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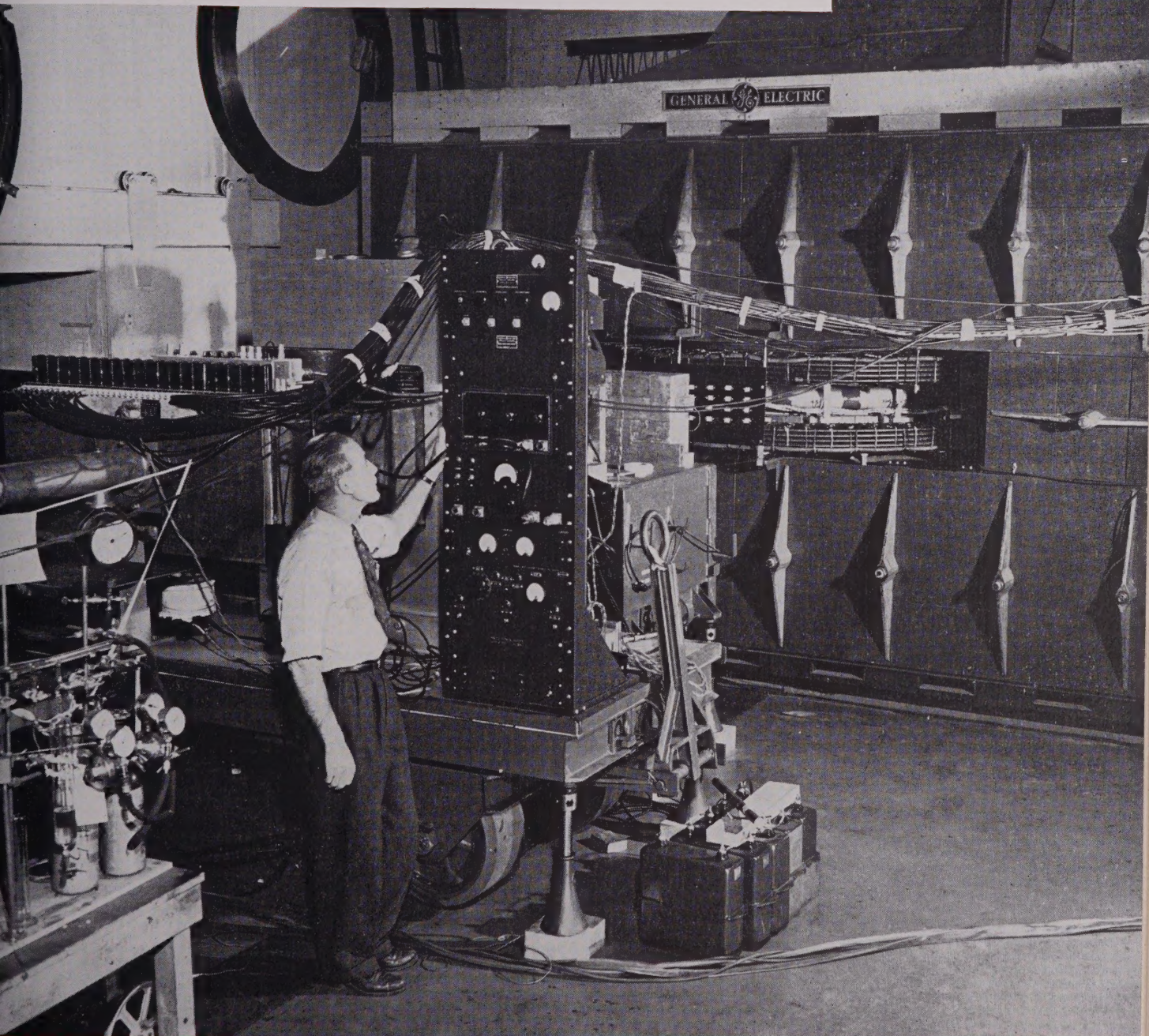
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REVIEW

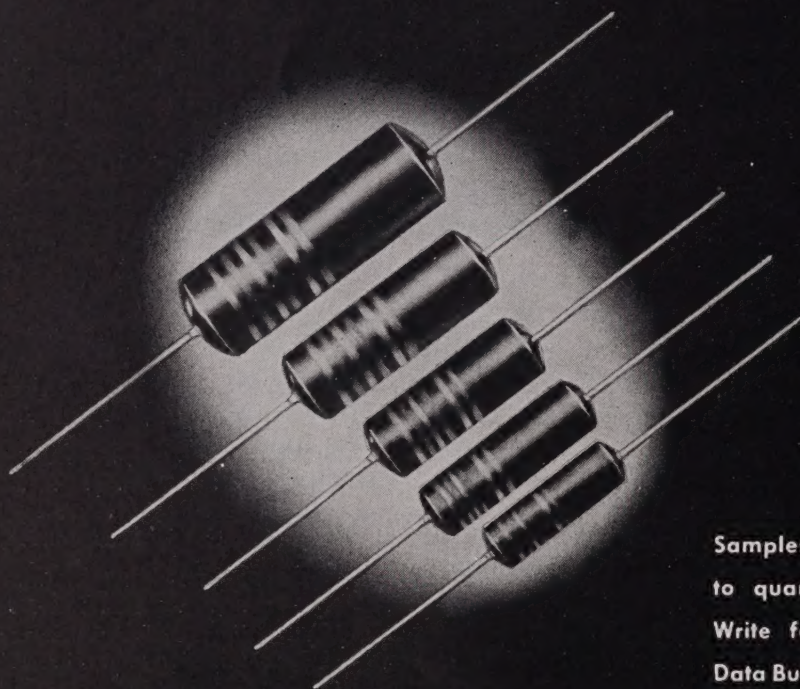
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MEASUREMENTS

October, 1948

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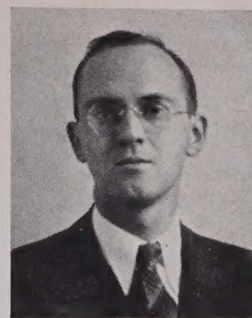
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INSTRUMENTS, PHYSICS, AND PHYSICISTS

A good measuring instrument is essentially a conveniently arranged physics experiment that can be repeated at will within specified accuracy limits

By G. F. GARDNER

General Engineering and Consulting Laboratory
General Electric Company



G. F. Gardner

THE tools most commonly associated with the engineering profession are variously represented as slide rules, T-squares, test tubes, gears, and similar devices, depending on the illustrator's imagination and the branch of engineering he wishes to represent. Having long been prejudiced in such matters, it has been my contention that none of these represents the class of tool used most universally by all engineers; namely, measuring instruments. With their help the user finds out things which enable him to purchase safely, design wisely, manufacture economically, and sell profitably.

As engineering grows more complex, it has been the common habit to associate measuring instruments with companies or groups specializing in design and manufacture. This is as it should be and the last few years have seen some marvelous advances in instruments which are accurate, sturdy, convenient to use, and capable of volume manufacture with all its attendant benefits. Before accepting this view and leaving all the instrument responsibilities to the instrument manufacturers with their well-arranged catalogs, let's think a little more about what a measuring instrument really is and why it acts the way it does.

EARLY PHYSICISTS SUPPLIED THE FUNDAMENTALS

I always like to think of a measuring instrument as a conveniently arranged physics experiment. If the experiment can be repeated within specified accuracy limits, the performance of the instrument is good. If the physics has been slighted in some respect, the performance is bad and we must get busy and put some more physics into it. It makes no difference whether it is the chemist's balance, the surveyor's transit, or the fuel gage on an airplane; if basic physical principles have been neglected, the performance is going to suffer.

Some of my friends say my definition is no good. Here they say is an instrument made in a physics laboratory and exceptionally sound as far as physical principles go but it is cumbersome to carry, awkward in its arrangement of parts, and practically impossible to repair or service. In other words, the emphasis is on the physics and not on the convenience.

I am not writing here pleading for the feelings of anyone who may have been unlucky enough to devise

a most useful and inconvenient measuring instrument. Rather, I think it might be fruitful to inquire what caused the physicist to make the instrument in the first place. It may have been that:

- (1). He had come across a phenomenon—an experiment which can be repeated within desired accuracy limits.
- (2). He was trying to make some measurement for which no suitable instrument was manufactured.

In regard to the first category, let's go way back to Robert Hooke. People had made springs for many years



ROBERT HOOKE

but no one really knew very much about them. In 1678 Hooke described an experiment made some 18 years before as follows:

"Take then a quantity of even-drawn wire either steel, iron or brass and coil it on an even cylinder into a helix of what length or number of turns you please, then turn the end of the wire into loops, by one of which suspend this coil upon a nail, and the other sustain the weight that you would have to extend it, and hanging on several weights, observe exactly to what length each of the weights do extend it beyond the length that its own weight doth stretch it to, and you shall find that if one ounce, or one pound or one certain weight doth lengthen

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

it one line, or one inch, or one certain length, then two ounces, two pounds, or two certain weights will extend it two lines, two inches or two lengths, and three ounces, pounds, or weights, three lines, inches, or lengths; and so forwards. And this is the rule or law of nature, upon which all manner of restituent or springing motion doth proceed, whether it be



HENRI BECQUEREL

rarefaction, or extension, or condensation and compression."

Now this very simple experiment enabled men to design useful spring balances, watch springs of predictable characteristics, tire pressure testers, gravimeters, and elastic members for more complex instruments. No doubt there was considerable adverse comment on Hooke's spring balance with an evenly divided scale; it was not self-contained but hung on a nail, the scale was not direct reading and it probably had other shortcomings. Nevertheless, here was something for the instrument maker to go to work on and provide with such useful features as temperature compensation, accurately drawn scales, and compact construction.

SOME ADDITIONAL HISTORICAL EXAMPLES

I assume that we could find in historical records dozens of similar cases; those also we could recount at considerable length but there is little point to that. The interesting thing is that some of the most useful and accurate instruments rely on some very simple facts once they are uncovered.

Had it not been for Newton, the measurement of displacements of millionths of an inch would not be such an easy undertaking. But Newton's explanation for the series of rings which appear when two almost perfectly flat glass plates are pressed together enables any high school physics student to detect displacements of millionths. It also helps the inspector in the finest tool rooms to check his gages with optical flats.

In 1879 Sir William Crookes showed that cathode rays could be deflected by a magnet, and in 1897 J. J. Thompson demonstrated that electrostatic means would deflect them as well. Both these facts would prove very useful if you wished to start manufacturing cathode-ray oscillographs. That is another obliging trait about physicists; they are always making useful observations and putting them on the shelf so someone else can come along later and build them into useful measuring instruments.

A good example in point is an observation made by Henri Becquerel in 1896; namely, that if a photographic emulsion is placed in a light-tight enclosure near a radioactive substance, the emulsion will show darkening upon development. First applied for the protection of x-ray technicians, this simple method is used today to insure additional protection for thousands of workers in the atomic-energy field. It is old but it is simple; it may have shortcomings but it gives a record. Yet it started as an observation by an alert and inquiring physicist.

I mentioned earlier that many instruments originated because some physicist wanted to measure something but there was no adequate instrument to do the job. Here, again, there are many examples to choose from but I like the story of Christiaan Huygens the best. He was studying the stars, so you would naturally expect him to improve the telescope. He did this as a matter of course, but one of the things which bothered him most was the inaccuracy of his time measure-



CHRISTIAAN HUYGENS

ments when making observations. So he applied the pendulum to regulate the movement of a clock. And two and one-half centuries of precise time keeping have started, culminating with the beautiful pendulum clock of Riefler and Shortt. These held supreme until some physicist investigated the vibration properties of quartz crystals and now we have crystal clocks, not so impressive looking as their predecessors, perhaps, but wonderful timekeepers just the same.

No difficulty, however great, could stand in the way of Albert Michelson's determination to measure accurately the velocity of light. So we can thank him for his interferometer which enables us to measure lengths by means of light waves. This quiet, resourceful physicist then undertook the work of measuring the standard meter in terms of the wavelength of cadmium light. Many of us would look on this as a distressingly laborious task, but not Michelson. For him, it was just a step on the way to his final triumph.

"He had taught the world to measure. They read the furnace and gauge

"By lines of the fringe of glory that knows nor aging nor age."*

MODERN INSTRUMENTS HAD EARLY BEGINNINGS

Many of us associate the mass spectrometer with the stirring events of the 30's, that later led to the Manhattan District Project and some subsequent spectacular demonstrations of applied physics. It's a long way back to J. J. Thompson's work in 1907, of course, so perhaps it's natural that many people tend to forget it. About 1918, however, things started to accelerate. Aston in England and Dempster in this country were grappling with the problems of making and using mass spectrometers. It is fascinating to read in the physics journals of the care which was taken and the difficulties which were overcome by many workers in bringing about the design of the present-day mass spectrometer. This instrument will keep the chemist and the instrument maker busy for another thirty years; the first in learning with it, and the second in improving it.

I mentioned the fascination of reading of the mass spectrometer in the physics journals. It seems, perhaps, a little foolish to go back to a 1918 reference when there are so many modern books written on the subject. Try it for yourself and see. If you are really looking for basic information on instruments you may be surprised at the clarity and the forthrightness with which the really basic facts are set down in the early writings. Also, if you're trying to build an instrument or design one, there's a good chance you'll have the same troubles and make the same mistakes that the early experimenter did.

When the need arose for unusual instruments in World War II, it was no accident that the physicist was called in on the measurement problems. Here was a situation in which he was thoroughly versed, a measurement to be made and no means with which to make it. To a rational engineer, some of the solutions sounded pretty frightful. Who, except an oil company, would mount a magnetometer in an airplane? Who, except a physicist, would put a radiation detector on a sniper's helmet? On the other hand, some of the solutions were beautifully simple.

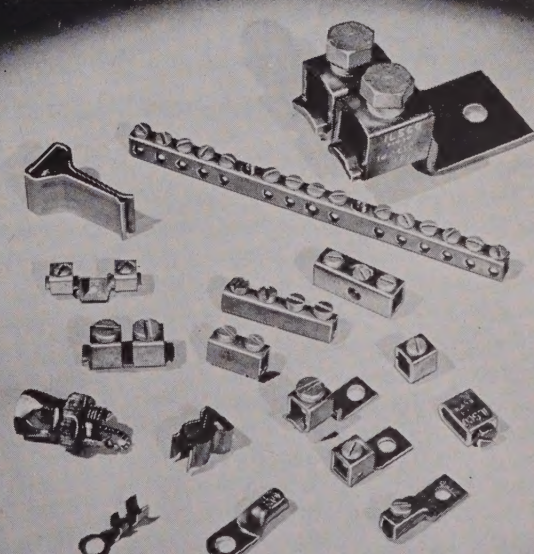
Take the case of Linus Pauling, the noted chemist, who was asked to make an oxygen detector. Lots of

people can think of complicated ways to do this. But Pauling thought about it and said: "Oxygen of all the gases, is the most magnetic." There is nothing particularly new about this fact; it has been known for more than a century. The difficulties in applying it to a direct-measuring instrument are of a very practical nature. The forces are extremely minute; it is even difficult to demonstrate the phenomenon in the laboratory. Before any one was able to discourage Pauling on the basis of a logical and practical argument, he went ahead and built an instrument based on sound physical principles: if the forces are small, keep the mass and moment of inertia at a correspondingly small value. And so we have Pauling's oxygen detector, so simple, and yet so neat in principle. It takes a good man to make new and simple things.

A MIGHTY TEAM

It was no accident that in September of this year the American Physical Society joined with the Instrument Society of America and other eminent engineering societies in a meeting at Philadelphia. This is a mighty team, the physicist, the instrument designer, and the instrument manufacturer, each giving of his special talents so that new measurement knowledge is rapidly available to serve industry and science. Will the progress ever slow down and the returns diminish? I don't think so. I have some friends who are physicists.

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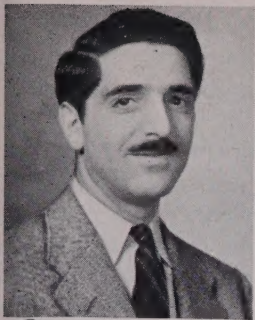
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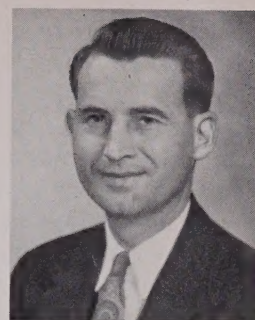


M. A. Princi

EXTENDING THE USEFULNESS OF LABORATORY INSTRUMENTS

In conjunction with various primary detectors, these instruments are flexible and versatile in electrical and other fields

By M. A. PRINCI and H. S. DAY
Instrument Engineering Division Electric Instrument Sales Division
Meter and Instrument Divisions, General Electric Company



Hudson S. Day

LITERALLY thousands of measuring devices have been developed for specific applications. However, since the measurement problems with which engineers and technicians are confronted daily are so broad and diversified, this article is intended to suggest approaches to measurement problems based upon utilization of existing laboratory instruments (Fig. 1).

The applications of electric instruments to the measurement of electric quantities are well known to laboratory personnel who are concerned primarily with electrical work. However, a great majority of the problems confronting laboratories today involve the measurement of nonelectrical quantities. In the fields of mechanics, physics, biology, and medicine, the need for improved measurement techniques is great and the potentialities of the electrical approach are frequently not recognized.

THE ELECTRICAL APPROACH

Many measurements which otherwise would be impractical because of physical limitations yield readily to electrical methods. For instance, in studying the feeding habits of grasshoppers, Professors Pepper and Hastings of Montana State College believed there was

a definite relationship between the insects' varying body temperature and where they do their feeding. Taking a grasshopper's temperature by the usual methods has not been reduced to practice, but by use of a small thermocouple (Fig. 2) and a standard laboratory potentiometer the measurement problem was readily solved.

The electrical approach to the measurement of non-electrical quantities involves the use of a primary detector which converts the measured quantity to a

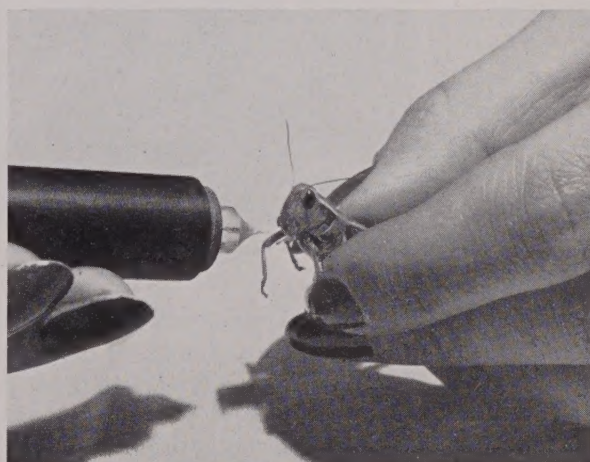


Fig. 2. Measuring the temperature of a grasshopper

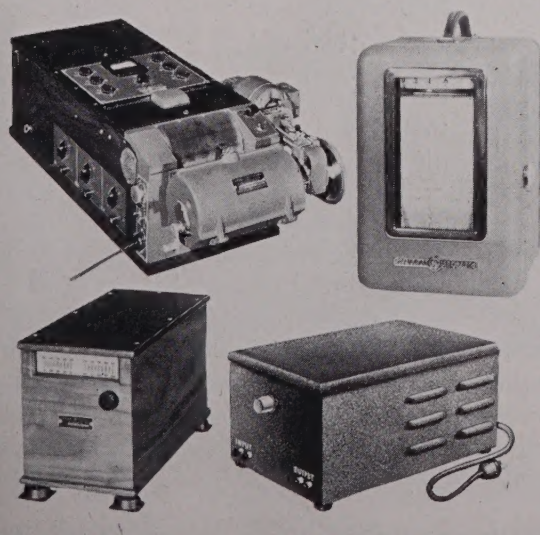


Fig. 1. Typical laboratory instruments: electromagnetic oscillograph (upper left), photoelectric recorder (upper right), light-beam galvanometer (lower left), and self-balancing potentiometer (lower right)

proportionate electric signal, and an end device which indicates or records its magnitude. Sometimes an intermediate means must be employed to either amplify the signal or to change its quality to make it better suited to the end device. Thus, the range of usefulness of many laboratory electric instruments can be extended materially by providing primary detectors for various nonelectrical quantities.

To facilitate realization of maximum benefit of the electrical approach, one group of measurement engineers has tabulated the more common primary detectors and outlined their range of usefulness, advantages, principle of operation, etc.⁽¹⁾ Even when mechanical instruments can be used to perform the measurement, the electrical method frequently is preferred because it is flexible and versatile, it permits

(1) Numbered references are listed at the end of the article.

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

remote indication or recording, it may be more precise, and it frequently provides a means of doing the job with the existing laboratory instruments.

Today, the use of electric instruments to measure nonelectrical quantities is so broad that even a general review of major applications is impractical. The following interesting applications will serve to illustrate the wide variety of measurement problems which have been solved by the electrical approach.

The Illinois Testing Laboratory was called upon to measure low air velocity in the study of circulation (FIG. 3). The problem was solved by the use of a primary detector which employs a heated filament the temperature of which changes as a function of air

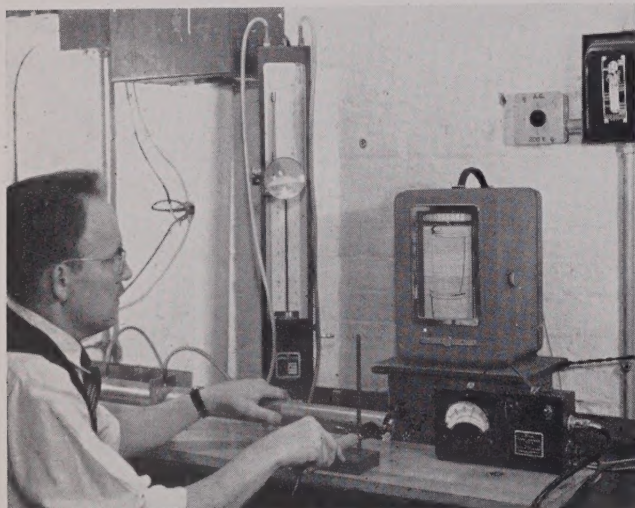


Fig. 3. Thermocouple applied to the measurement of low air velocities

velocity. A sensitive photoelectric recorder provides a record of the minute temperature changes of the detecting element. The same recorder is used with other primary detectors for measuring light intensity, electrical phenomena, and various other quantities.

MATERIALS SELECTION

An unusual application of the self-balancing potentiometer shown in FIG. 4 saved many hours of tedious tests in the laboratory. A rather large quantity of laminations of different ferrous materials had been stored in a single container. The various kinds of iron were not identifiable by inspection, but it was known that the materials included were nicaloi, silicon steel, permalloy, and mumetal. The principle employed to sort the materials consists of establishing two thermal junctions on each piece of the material being sorted. Two identical iron probes are used. A small heater encloses one of the probes and raises its temperature to some arbitrary constant value. The other probe is held at room temperature. When the two probes are applied to the sample being sorted, the potential difference between the two junctions appears at the input of the self-balancing potentiometer. The output of the potentiometer is connected to a milliammeter indicating the magnitude of the potential difference.

Before starting the sorting operation, a sample of known material to be sorted is applied to the probe and the millimeter deflection noted. All samples of this material will result in the same deflection of the millimeter as long as the temperature of the hot junction is maintained constant. Similarly, each of the other materials can be sorted, provided the range of thermal emf is sufficiently wide to insure the proper selection. The inherent accuracy of the system is sufficient to permit readily sorting materials that have thermal emf's differing by two percent.

CHEMICAL ANALYSIS EMPLOYING FLAME PHOTOMETER

Flame photometry has been employed in quantitative chemical analyses in several diversified arrangements.⁽²⁾ FIG. 5 illustrates one form of this device which has been employed by Dr. W. M. Wallace and Miss M. Cushman of Harvard University in connection with research on the treatment of diabetic coma and heart disease. An atomized solution of the body fluid containing either sodium or potassium is carried through the base of a gas burner into the flame and ignited. The color of the light arising from the flame will, of course, be characteristic of the element being determined. By means of two barrier-layer light-sensitive cells and a system of filters, the intensity and quality of the light falling on the two cells after filtering

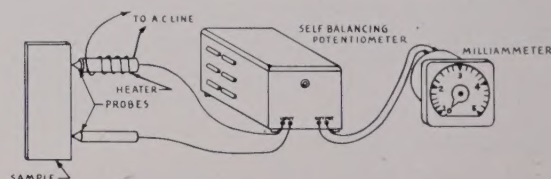


Fig. 4. Functional diagram of the materials selector

furnishes a quantitative indication of the presence of the element being studied.

Referring to FIG. 5, two slits are provided in the burning chamber so that light may fall on each of two mirrors and be reflected to the respective photoelectric cell. One of the cells is covered by a lithium filter, thus rejecting radiation other than that characteristic of lithium. To the other photocell is applied either the sodium or potassium filter. The ratio of light intensities on the two light-sensitive cells is indicated by the potentiometer settings when the galvanometer reading is zero. This ratio when compared with the initial calibration curve provides the measure of sodium or potassium in parts per million in the solution being tested.

In this and other applications the flame photometer has reduced considerably the time required to obtain quantitative chemical analysis over that required by conventional wet methods.

STRAIN MEASUREMENT

Since the early development of the wire strain gage⁽³⁾ it has been successfully applied for the measurement

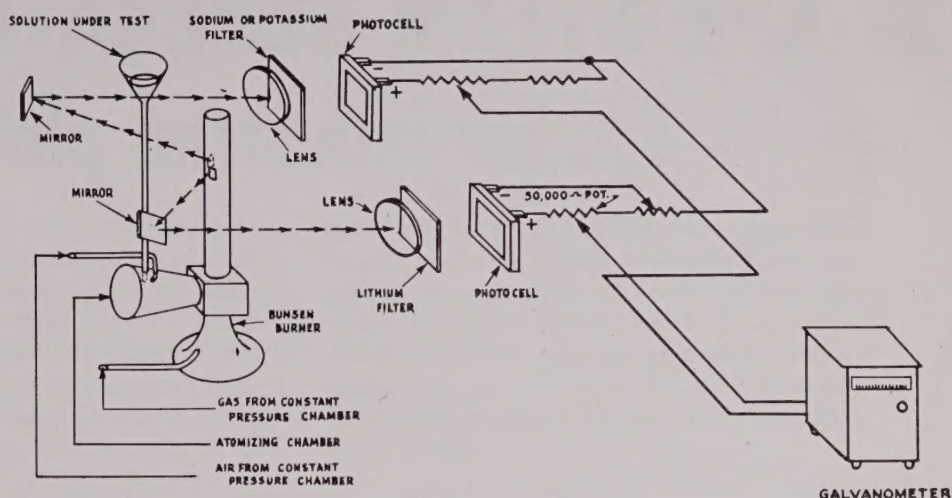
of strain and vibration in both static and dynamic tests of structural members and rotating shafts.

A novel application has been made of that primary detector by a steel company to adjust rolling-mill

obtained on the chart, which is calibrated in terms of micro-inches per inch.

The particular features of this scheme are: first, the wide range of strain which the system is capable

Fig. 5. Functional diagram of a typical flame photometer



pressures (FIG. 6). When adjusting the roll pressures, standard test blocks are used on which are mounted the wire strain gage. FIG. 7 shows the circuit arrangements in which a photoelectric recorder is employed to indicate changes in strain. This scheme furnishes a ready means of obtaining a continuous record, and, because of its fast response of one-third second full scale, has made possible more precise roll adjustments than would be possible by conventional methods.

In the circuit in FIG. 7, the wire strain gage is connected in a bridge circuit which is excited from a local oscillator. The output of the bridge is amplified and applied to a discriminator network which is energized

of recording; and second, the rapid response of the instrument.

CONCLUSIONS

The importance of measurements to practically all phases of laboratory work emphasizes the need for more information which will facilitate the solving of

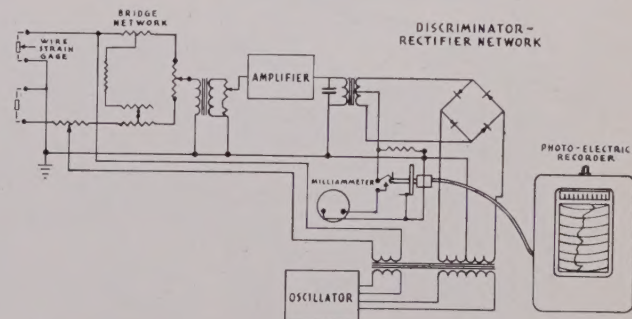


Fig. 7. Functional diagram of the wire strain gage employing a photo-electric recorder



Fig. 6. Wire-strain-gage equipment for studying strain in rolling-mill machinery

om the same local oscillator. The output of the discriminator is rectified and connected to the photoelectric recorder; thus rapidly increasing and decreasing magnitudes of strain can be recorded. The bridge requires only simple adjustments before the test is initiated, and thereafter a continuous indication is

day-to-day problems. The range of usefulness of existing laboratory electric instruments frequently can be extended to the measurement of nonelectrical quantities if the fundamentals are understood. Armed with a few basic laboratory instruments and a knowledge of the more common primary detectors, the engineer or physicist can take full advantage of the tools already at his disposal.

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- (2) "Improved Method of Flame Photometry," by J. W. Berry, D. G. Chappell, and R. B. Barnes, *Ind. & Engng. Chem.*, vol. 38, Jan. 1946.
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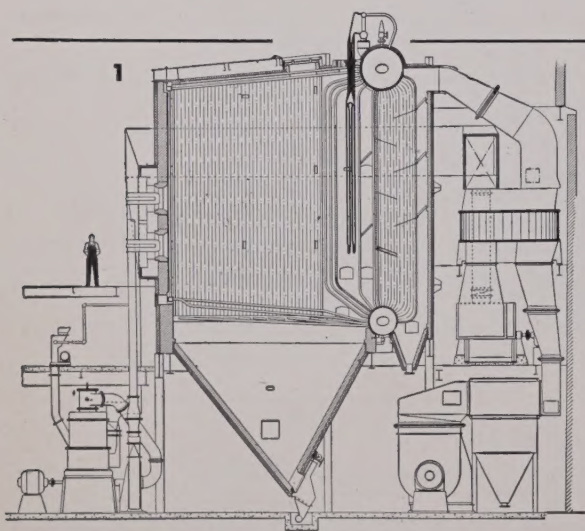
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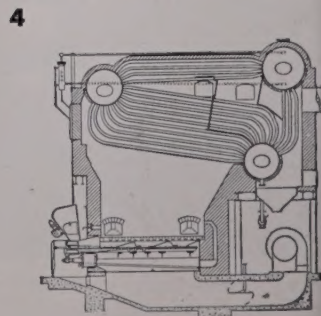
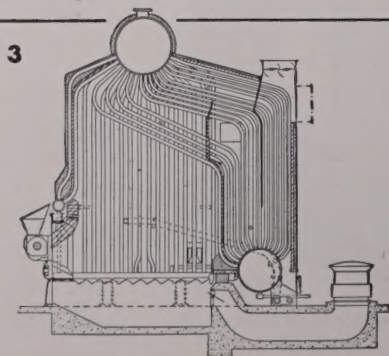
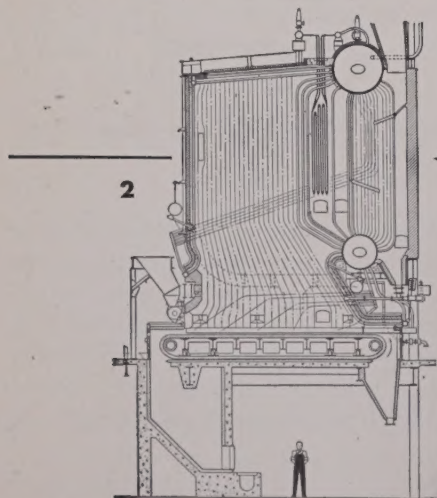


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DETECTION AND LOCATION OF FAULTS IN FHP MOTOR STATOR WINDINGS

Testing technique developed for each type of motor employs equipment that applies the type of voltage transient encountered in service

By M. C. HALLECK
Fort Wayne Works Laboratory
General Electric Company



MUCH work has been done, but very little written about, the potentialities and possible applications of the winding-insulation tester described in this article. Hence a brief review will be given of why such a machine was needed and how it operates, and then an outline of a few applications where the testing equipment, when used properly, is an aid in producing a better quality product.

For many years electric equipment was tested for possible insulation failure by simply applying power-frequency potential between one end of the winding

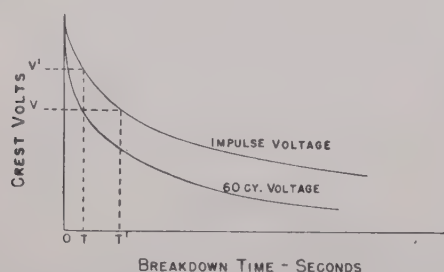


Fig. 1. Comparison of insulation breakdown time for power-frequency voltage and impulse voltage

and ground. This test proved to be adequate for testing conductor-to-ground insulation but gave no information about the equally important turn-to-turn and layer-to-layer insulation strength.

To apply a voltage stress between turns, a high-frequency test was introduced. The frequency range of the test equipment was about 1000 to 1200 cycles per second, and was used many years to indicate faults in fractional-horsepower motors. This test proved to be an important link in improving the design and quality of electric equipment but failures still occurred in service.

It was later found that these failures were caused by high-voltage transients which appeared across the line terminals. These transients were chiefly caused by circuit interruptions and lightning. As a matter of fact, switching surges as high as 3000 volts have been observed on 115- and 230-volt lines. The duration of the transient is very short: the voltage rises to its crest in approximately one microsecond. As a result, these voltage transients produce a very high stress between turns in the winding. To raise the high-fre-

quency test equipment's voltage sufficiently high to simulate that stress between turns requires such high densities that this method of test is not practical.

THEORY

Experiments have shown that it takes a certain length of time for insulation to break down when a sine-wave voltage of low frequency is applied. It takes quite a different length of time when an impulse voltage of the same amplitude is applied. FIG. 1 will illustrate that characteristic difference more clearly. Both of the voltage vs breakdown time curves relate to similar windings. One curve is of 60-cycle sine-wave voltage vs breakdown time, while the other is of surge voltage vs breakdown time. If a peak voltage V is held constant, the time to breakdown is OT seconds on the 60-cycle curve, while it is OT' seconds for the impulse voltage curve. If, on the other hand, the breakdown time is held constant, say OT seconds, the peak voltage on the impulse test may be increased to OV before the winding will break down. These curves are

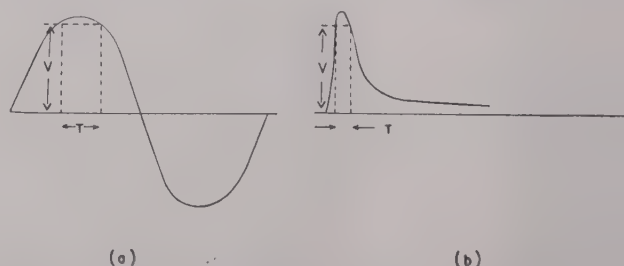


Fig. 2. Comparison of surge time in a sine wave (a) and impulse wave (b) with identical voltage input

only qualitative and represent no particular winding. Each type of winding will have its own particular curves.

It has been found⁽¹⁾ that certain single-phase induction stator windings will withstand, for the same length of time, an impulse voltage 1.7 times as high as a 60-cycle sine-wave voltage. This difference between the two curves in FIG. 1 may be explained by noting the difference in length of time the voltage is above a certain value in any one second. In FIG. 2(a) the voltage above a certain value V will be the amount that will be the most effective in producing insulation failure. Lower values do cause stress but its degree is relatively

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(1) Numbered references are listed at the end of the article.

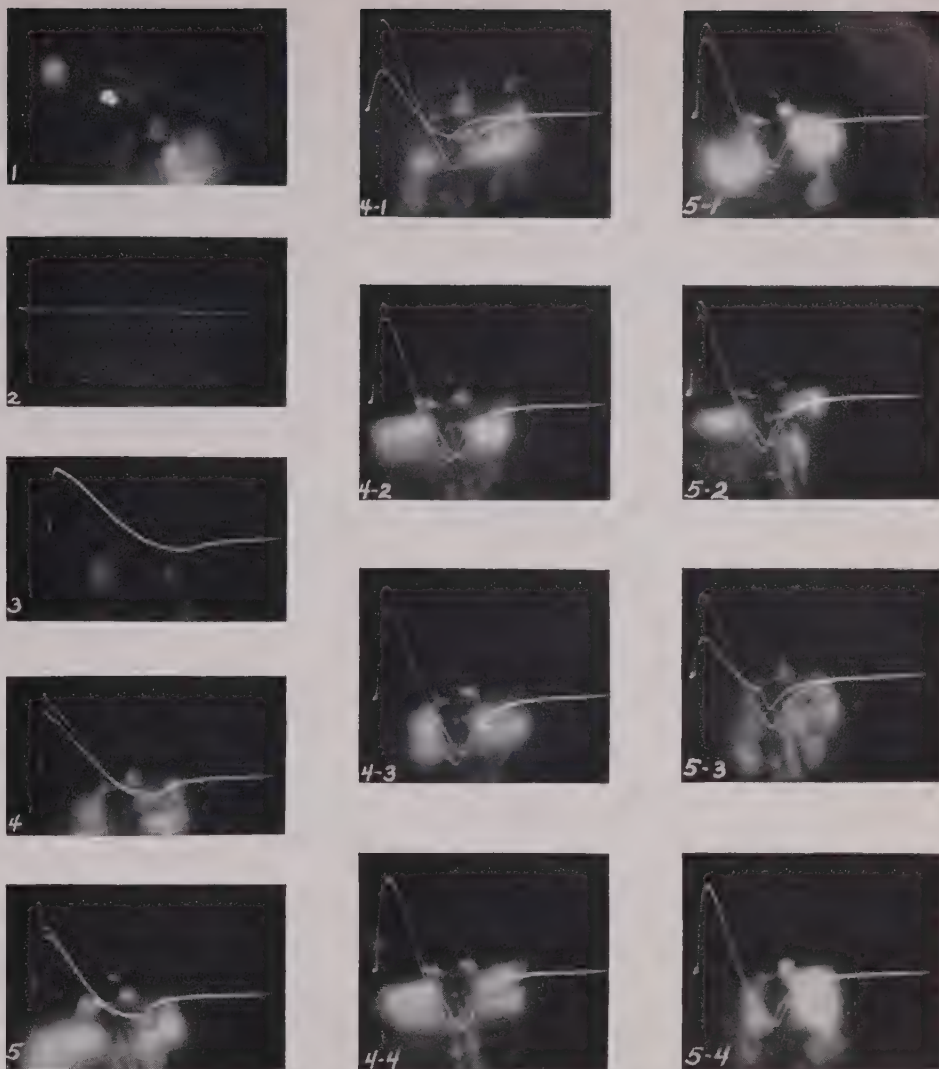


Fig. 4. Typical wave forms and calibration trace shown by oscilloscope in winding tests

- (1) Good Winding (abnormally wide sweep)
- (2) Calibration for (1)
- (3) Good Winding (Normal Sweep)
- (4) Shorted Turns in one stator winding
- (5) Shorted Turns in another stator winding
- (4-1) Auxiliary Pickup Coil 1, with stator winding (4)
- (4-2) Auxiliary Pickup Coil 2, with stator winding (4)
- (4-3) Auxiliary Pickup Coil 3, with stator winding (4)
- (4-4) Auxiliary Pickup Coil 4, with stator winding (4)
- (5-1) Auxiliary Pickup Coil 1, with stator winding (5)
- (5-2) Auxiliary Pickup Coil 2, with stator winding (5)
- (5-3) Auxiliary Pickup Coil 3, with stator winding (5)
- (5-4) Auxiliary Pickup Coil 4, with stator winding (5)

unimportant compared to that resulting from values above V . The voltage amplitude is seen to be V or above for a certain time T .

In FIG. 2(b), the impulse voltage is above V for a much shorter time. Thus if both voltages reach this crest the same number of times per second, the accumulated length of time the voltage is above V on the sine-wave voltage is much longer than on the impulse voltage. By the same reasoning, the impulse voltage may be raised above the 60-cycle voltage before equivalent insulation deterioration takes place. As a corollary, the impulse voltage is above the nominal value

for a much shorter period of time than the 60-cycle sine-wave voltage, hence the injury to the insulation will be less.

It is common knowledge that the voltage distribution in windings may change with frequency. The voltage distribution produced by the complex surge voltages occurring in service will be nonlinear. Therefore it became evident that the test equipment needed should apply the same type of voltage transient as that found in service.

OPERATION

The schematic circuit diagram of the resulting winding-insulation tester is shown in FIG. 3. A voltage coming from the trigger circuit, which is also part of the sweep circuit, causes thyatron 2 to carry current, thereby discharging capacitor 3 into the winding of two single-phase induction stator windings. The capacitor was charged on the previous half-cycle by the transformer through rectifier tube 1. Thyatron 2 is triggered once each cycle of the power frequency; thus there is a voltage surge every cycle. By using the synchronous reversing switch, the surge on the first half-cycle may be sent through the main, or run, winding of the test

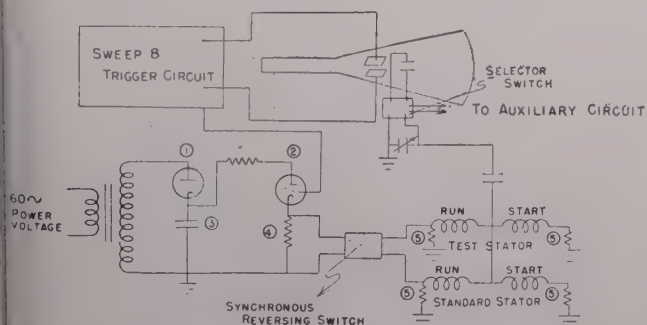


Fig. 3. Schematic diagram of winding insulation tester

stator and back through the run winding of the standard stator to ground. On the next half-cycle, the surge will travel through the run winding of the standard stator and back through the run winding of the test stator to ground. By connecting the oscilloscope midway between the two run windings, it is possible to view the wave pattern produced by each winding. If the two windings are alike in every respect, the wave from one winding will match the wave from the other winding and the two waves will superpose and appear on the scope as but one wave, as shown in FIG. 4(3). If the windings are not alike, two waves will appear as indicated in FIGS. 4(4) and 4(5), the result of shorted turns.

fied by the type of wave pattern shown on the scope.

Voltage measurements taken at intervals along the run winding indicated a nonlinear voltage distribution. At some points the voltage even exceeded the input surge voltage.

FIG. 5(a) shows the voltage to ground at each pole coil in the run winding of a four-pole induction stator. This distribution of voltage is the result of reflected waves and inductive and capacitive coupling between turns in the winding. Since the individual stator coils are random-wound, the inductive and capacitive coupling will not be uniform. Thus it would be very difficult to calculate the voltage that would be present in any

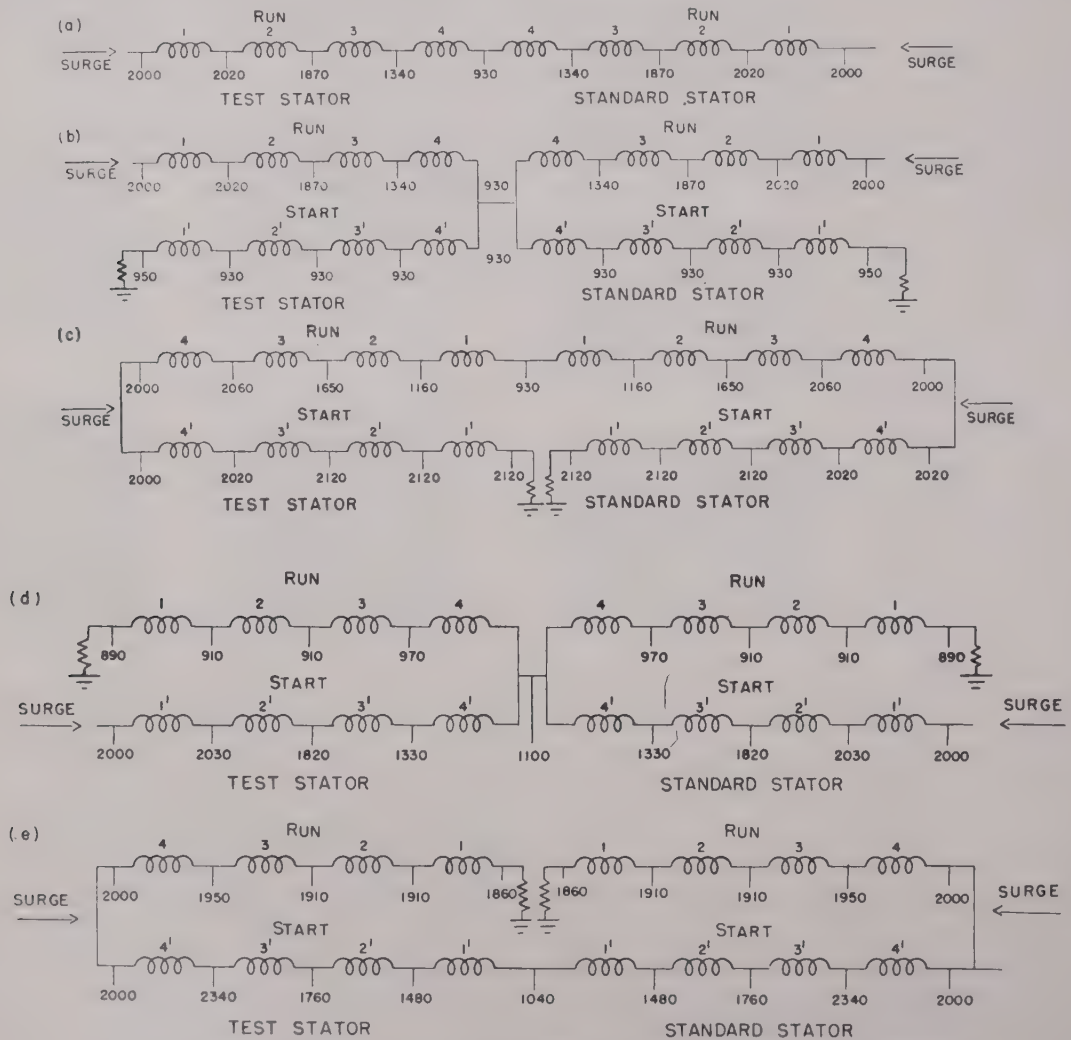


Fig. 5. Voltage to ground at each pole coil in a four-pole stator being tested with the winding tester synchronous switch operating. Various arrangements are shown in (a) to (e) inclusive

The winding insulation tester was originally designed to produce a surge voltage which would reach crest in one microsecond and fall to half-crest on the wave tail in $5\frac{1}{2}$ microseconds. A typical calibration wave is included in FIG. 4(2) for a wave pattern such as that shown in FIG. 4(1).

It has been found by experience that different patterns on the scope are caused by different kinds of faults in the winding, and also that similar faults give similar patterns. By this means, faults may be classi-

portion of the winding. For that reason the voltage distribution is determined by test.

It is quite evident from FIG. 3 that some sort of voltage will be present also in the start winding. This voltage may be produced either by induction or by direct coupling, or a combination of the two. FIG. 5(b) shows the voltage to ground at each pole coil in the start winding, while the run winding is being surged.

In FIG. 5(a) coil 1 has 2000 volts at the beginning of the winding while coil 4 has only 930 volts at the end

of the winding. This means that coil 4 has roughly half the surge voltage found in coil 1. A similar voltage distribution would be found in the winding when in actual service if a transient voltage of the same magnitude enters at coil 1.

Since, in service, voltage transients may enter at either end of the winding it is necessary to initiate the

different. FIG. 6(c) shows another method in which the winding may be surged.

Therefore using the winding-insulation tester does not mean merely connecting the leads to the machine and observing the pattern. In order to control the test, a preliminary analysis of the surge must be made to determine whether the voltage distribution is the type

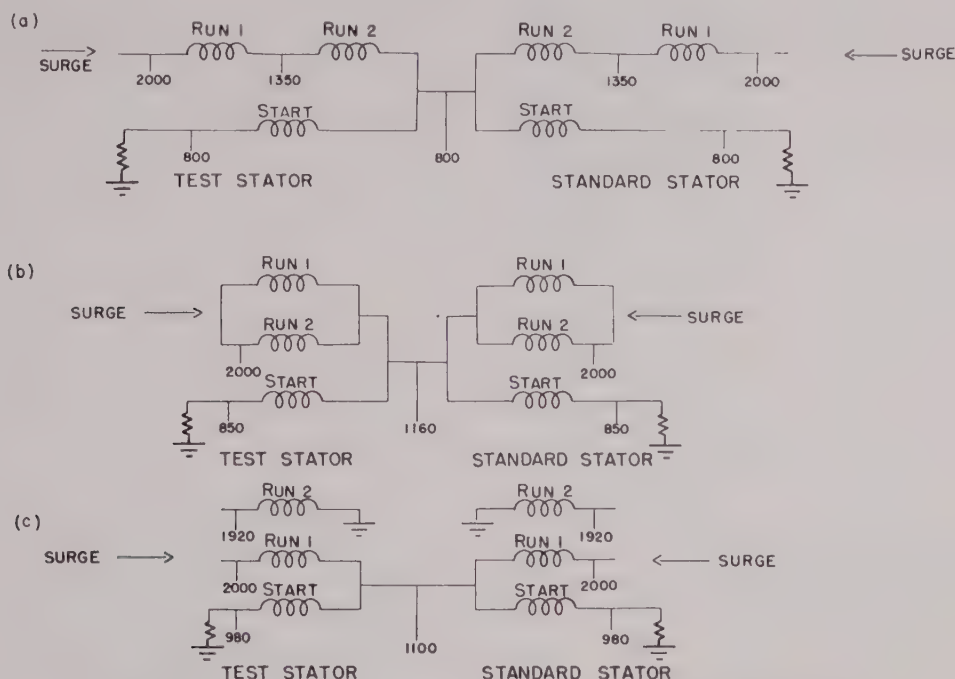


Fig. 6. Voltage to ground at each pole coil in a 110-220-volt four-pole stator being tested in various arrangements (a) to (c) with the winding insulation tester switch operating

test surge at every terminal. By operating another switch located between the synchronous reversing switch and the winding (not shown in FIG. 3), it is possible to quickly reconnect the winding so that eventually all line terminals will be surged.

FIGS. 5(b)(c)(d)(e) show the four possible connection combinations and the voltage to ground at each pole coil. FIGS. 5(c) and 5(e) show the two combinations where the surge may enter at the common connection for the start and run windings. In these instances the voltages in the open winding are quite high. The resistance to ground shown at the end of the winding helps reduce these voltages considerably; otherwise they would be much greater than indicated in the diagrams.

APPLICATION

There are many types of windings used in the manufacture of motors. Each type will have its own characteristic inductive and capacitive coupling, and that will result in a particular voltage distribution for that winding. For example, FIG. 6 shows a combination 115/230-volt stator winding. Surging the two windings connected in series (FIG. 6(a)) gives a certain voltage distribution in the winding. If the two run windings are looked in parallel (FIG. 6(b)), as would be the case for a 115-volt line, the voltage distribution is quite

desired, and to be sure there are no excessive voltages in adjacent windings.

The winding-insulation tester is not limited to the surge testing of motor windings. In the manufacture of reactors and small transformers, cases have been found where rearranging the leads greatly increased the insulation strength. Also, points of weakness were strengthened by adding insulation to those weak spots. Some cases were found where the insulation was stronger than necessary. All this valuable information was obtained by noting the potential at the instant failure occurred on a number of samples when using the winding-insulation tester. As a result, the quality of the product has been greatly improved.

AUXILIARY EQUIPMENT

Several years' use of the winding-insulation tester in the manufacture of fractional-horsepower motors has proved its value in improving the quality of the motors. In fact, this device is used in testing all motors of several types.

When adopting the winding-insulation tester, a need arose for more accurately locating the faults in the winding. The tester itself will indicate whether a fault is present in the entire winding. Early methods for more accurately locating faults consisted of discharging a capacitor into a small auxiliary winding placed

close to the winding under test. If there were shorted turns present in this part of the winding, current produced by transformer action would flow in the auxiliary winding. The current was indicated by an

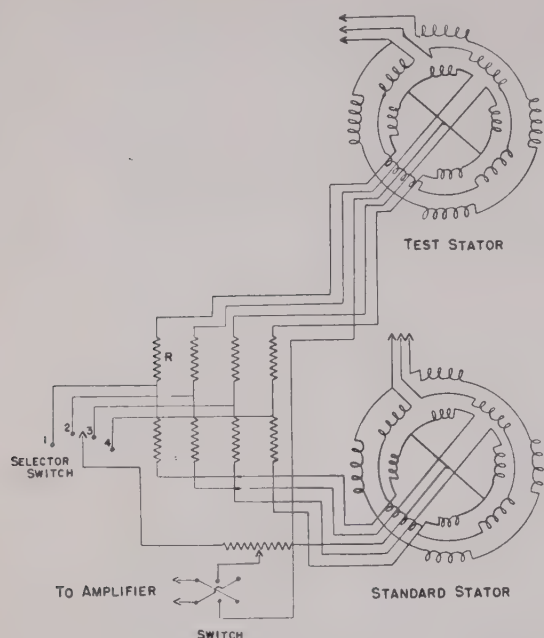


Fig. 7. Circuit diagram of pickup coils in single-phase induction stator windings

adequate ammeter. The device proved very helpful in locating shorted turns but would not locate other types of faults indicated by the winding insulation tester.

A later method employed the winding-insulation tester with some auxiliary equipment for locating faults. The equipment consists of small pickup coils placed over each set of windings, as indicated in FIG. 7. Transformer action between the winding and the pickup coils induces in those coils a low voltage, which is then picked up and amplified, and connected to the plates of the scope in the winding tester.

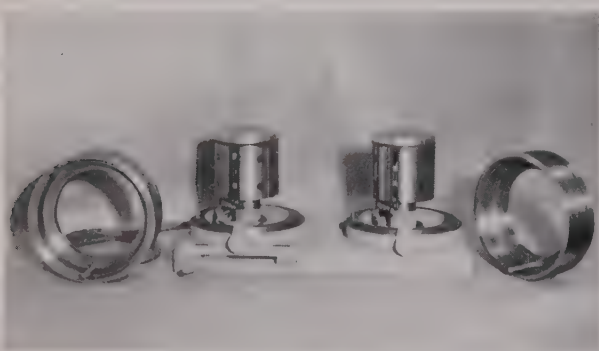


Fig. 8. Auxiliary equipment for locating faults

The coils are connected together through resistance R which is center-tapped and connected to the amplifier. In this manner two patterns appear on the scope, indicating the condition of that portion of the winding

on a standard and a test stator. By switching to the pickup coils, an individual coil of a stator can be compared with a coil of a standard stator. The pickup coil showing the worst condition indicates that portion of the winding at fault.

FIG. 8 shows the construction of the pickup coils for both the standard and test stators. The arm at the left front is for rotating the pickup coils to either the main or the start winding. This arrangement eliminates an extra set of coils for the two windings.

The amplifier is a two-stage class A amplifier having an amplification of 80 to 1 and was purposely designed for a long narrow space. FIG. 9 shows the schematic diagram of the amplifier. Since the pulse voltage is

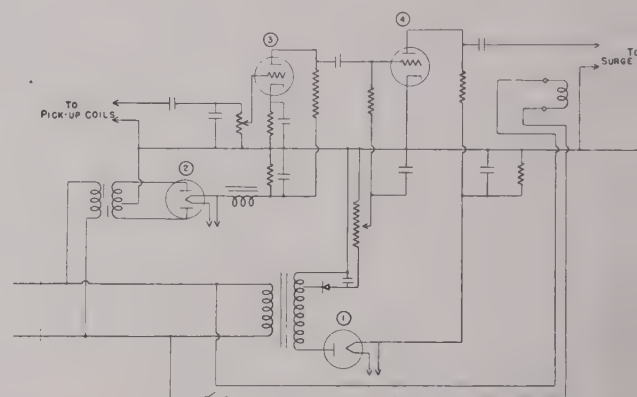


Fig. 9. Schematic diagram of amplifier circuit used with auxiliary equipment

one direction only, the pickup voltage will also be in one direction. Thus the bias on tubes 3 and 4 may be adjusted to give good response to this single-direction impulse voltage.

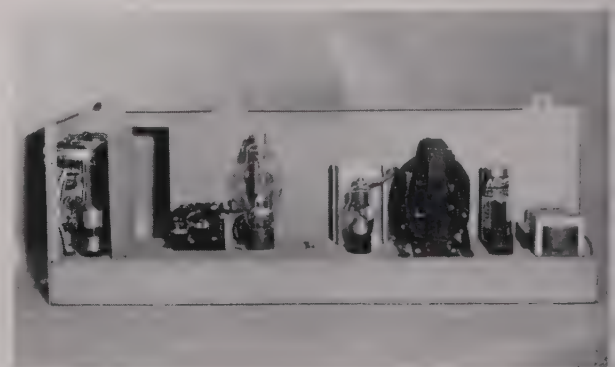


Fig. 10. Arrangement of transformers and tubes in amplifier

FIG. 10 shows the arrangement of the transformers and tubes in the long narrow chassis. The first stage of amplification was shielded to guard against stray pickup. The switches were all placed on the front of the amplifier chassis for ease of operation. By constructing the auxiliary equipment in this manner the surge tester is not disturbed except for bringing out two leads from the scope.

FIG. 11 shows the actual factory set-up of the winding-insulation tester and its auxiliary equipment.

FIG. 4 shows the type of patterns observed on the screen when using the winding-insulation tester first to indicate a fault and then (using also the auxiliary equipment) to accurately locate the fault. FIGS. 4(4) and 4(5) typically indicate shorted turns in the winding. FIGS. 4(4-1) (4-2) (4-3) (4-4) are the patterns produced by the voltage induced in the pickup coils by the stator winding that produced pattern FIG. 4(4).

FIGS. 4(5-1) (5-2) (5-3) (5-4) are the patterns produced by the voltage induced in the pickup coils by the stator winding that produced pattern FIG. 4(5). Patterns in FIGS. 4(4-1) and 4(5-3) are quite different from the others in their groups and thus show that the portion of the winding adjacent to that pickup coil is at fault. With the additional equipment, and an experienced operator, it is possible to determine the type of fault and the location of the fault.

CONCLUSIONS

There have been considerable strides made in improving test equipment to more nearly simulate voltage transients found in service. These transients impressed

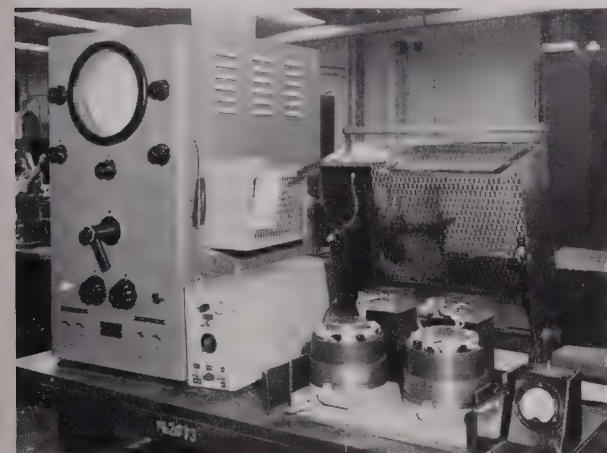


Fig. 11. Winding insulation tester and auxiliary equipment set up for factory tests

on a motor winding produce a definite voltage-distribution characteristic for that winding. Therefore, the testing technique for each type of motor must be developed experimentally. To improve quality, many types of windings are surge-tested 100 percent with the insulation tester described in this article. Auxiliary equipment used with the tester has been adopted to isolate faults.

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- (3) "A New Instrument for Analyzing Electric Transients," by N. Rohats, *GENERAL ELECTRIC REVIEW*, vol. 145, February 1942, p. 121.
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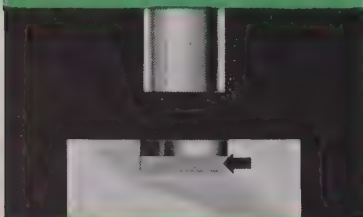
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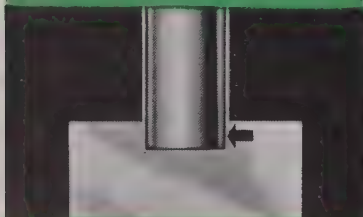
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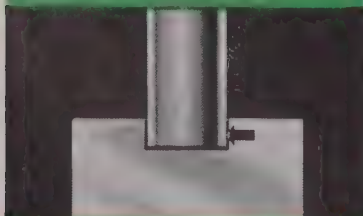
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3. The space between the die and punch determines wall thickness. The external design features are incorporated in the die, the internal in the punch.

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John W. Teker

DETERMINING TEMPERATURES OF TRACTION MOTORS

**Description of instruments and techniques
devised for temperature measurements on
diesel-electric traction motors in service**

By J. W. TEKER

and

F. H. CATLIN

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Erie Works Laboratory



F. H. Catlin

OCCASIONALLY in diesel-electric locomotive applications, special duty cycles are encountered that make highly desirable the determination of the temperatures of the traction-motor windings while in service. This article describes the instruments and techniques devised for such work.

Under some conditions, it is considered good application practice to utilize the full ability of a locomotive beyond its normal continuous rating provided the motor or generator windings do not exceed predetermined safe temperatures for a duration of time sufficient to damage or to unduly shorten the insulation life. Severe overheating in a single instance may be sufficient to shrink wedges and relax bands without causing immediate failure, but subsequent movement of the winding under influence of vibration will cause the insulation to wear through and fail by short circuit or by grounding even before complete deterioration of the insulation.

The ability of a diesel-electric locomotive to handle overloads is dependent upon the thermal capacity of the electric apparatus, so that the duration for which an overload may be maintained without harm is determined by the temperature of the windings just preceding the application of the overload.

From track profile, train tonnage, and certain carefully chosen assumptions, experienced personnel can calculate the approximate maximum winding temperature that will be reached in a given service. When marginal applications occur, a measurement of winding temperature is necessary to determine more closely the factor of safety.

BASIS OF TEMPERATURE MEASUREMENT

It is impractical to measure directly the temperature of windings assembled in a motor under a locomotive, but it is practical to measure the electrical resistance of the winding. The temperatures can then be calculated from this resistance measurement, since it is known that as the temperature of copper changes there is a corresponding change in its electrical resistance.

Therefore, it is only necessary to measure the cold resistance r of the windings in question after the motors

have stood without power long enough for all parts to reach a uniform temperature t . This temperature is measured with thermometers placed on the motor parts. The hot winding resistance R , obtained in actual service, is measured at prearranged stops where the maximum motor temperatures are expected. The hot temperature T can be calculated from the relation $T = (R/r) (234.5 + t) - 234.5$, wherein the temperatures are all in degrees centigrade.

For the purpose of making the service measurements, the motor-field windings are connected to the measuring instruments, located in the locomotive cab, by temporary wiring and suitable switches so that the required readings can be quickly made. The armature resistance is obtained by selecting a span of the armature winding to which connection is made by a special yoke applied by hand pressure to the commutator through the motor inspection opening. Connection between contacts of the yoke and the instrument station is made through a multiple-wire flexible cable. This auxiliary equipment is coiled and carried in the cab between points where stops are made for measurements.

It is of course necessary to remove power from the motors and bring the train to a stop before the resistances can be measured. During this interval the motors are cooling. For this reason, the temperature of the winding as determined at the instant when the resistance is obtained is considerably lower than the actual temperature of the winding when power was removed. The difference is represented by the amount of cooling taking place during this elapsed time. The rate of this cooling can be determined by recording the time interval between the instant power is removed and the time each resistance is read, and then plotting the values as temperature with respect to time. A curve drawn through these points and extended (in accordance with accepted cooling-curve practice) to the power-off time will give the most probable temperature at that instant. Obviously, a minimum elapsed time will give the greatest accuracy.

NEED OF SPECIAL MEASURING EQUIPMENT

While this method is recognized as the most reliable means for motor-temperature determination by laboratories and test floors throughout the electrical industry,

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Fig. 1. Electronic converter and balancing motor used in detecting bridge balance

attempts to apply it to diesel-electric locomotive service tests were disappointing. Series-wound traction motors, with low-resistance components, made the use of a Kelvin double-bridge desirable; but for testing locomotives in service it was found extremely difficult to use the conventional suspension-type galvanometer with this bridge. Engine vibration affected the galvanometer so seriously that time was lost and readings were erratic. The cooling curves so obtained were unsatisfactory and questionable. Engines cannot be shut down during the making of these measurements because tests with scheduled revenue trains must be made with minimum delay. Continued operation of the diesel engines and air compressors during the stop is necessary to permit recharging the air-brake system in order to make a quick start as soon as measurements are finished.

Because of the unsatisfactory experience with conventional suspension-type galvanometers in that application, an electronic method of detecting bridge balance was adopted.

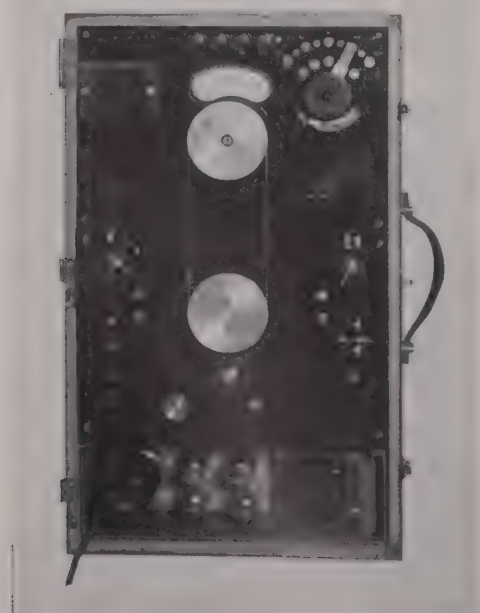


Fig. 2. Portable self-balancing bridge complete with converter and balancing motor, and resistance bridge; but without cover

THE EQUIPMENT DEvised

The electronic converter and balancing-motor unit shown in FIG. 1 was found to have the required sensitivity and was not affected by vibration. This unit receives the out-of-balance emf from the bridge, converts it to alternating current, amplifies this voltage, and uses the amplified voltage to excite one winding of a split-phase motor. The direction of rotation of the motor is dependent upon the polarity of the direct-current emf received from the bridge.

The complete instrument assembly shown in FIG. 2 contains a resistance bridge from which the galvanometer had been removed and the galvanometer connections wired to the input terminals of the converter. The knob provided to rotate the resistance dial of the bridge was removed and a pulley mounted in its place.

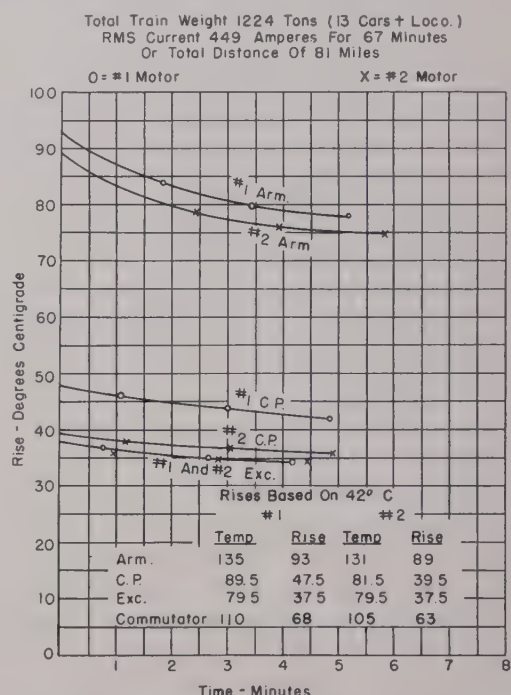


Fig. 3. Typical cooling curves obtained with the self-balancing bridge
Arm: Armature winding
C.P.: Commutating-pole field
Exc: Main field

The balancing motor was used complete with gear and slide-wire drive and coupled to the pulley mounted on the bridge resistance-dial shaft.

With this arrangement, the instrument becomes a self-balancing resistance bridge, and upon application of power to the bridge circuit any unbalance of the bridge causes the balancing motor to so rotate that the bridge dial is moved in the correct direction to restore balance. Full rotation of the dial is obtained in approximately 30 seconds. As soon as balance is achieved the resistance value is read directly from the bridge dial. Vibration in no way affects the accuracy of balance.

This special instrumentation, with attendant auxiliary equipment, reduces the technique and skill required to a point where measurements can be made under adverse service conditions with a speed and accuracy equal to, or even surpassing, those obtained under more favorable test-floor conditions.

Total Train Weight 926 Tons
RMS Current 619 Amperes
For 20 Minutes

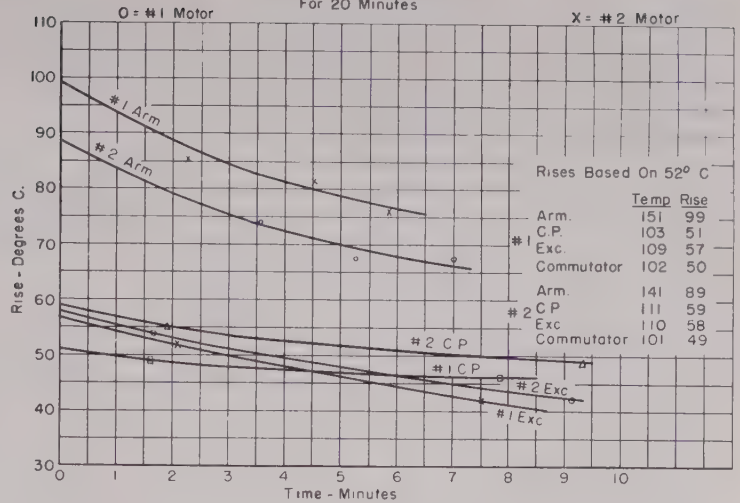


Fig. 4. Typical cooling curves previously obtained using conventional instruments
Arm: Armature winding
C.P.: Commutating-pole field
Exc: Main field

APPLICATION AND RESULTS

Field tests were made consisting of three resistance measurements on each of four fields and two armatures in an elapsed time of less than six minutes from the time of power removal to the time the train was ready to proceed again after completion of the measurements.

FIG. 3 shows a typical set of curves obtained by these measurements for the armature, commutating-pole, and main field. FIG. 4 shows a set of similar curves made from the inadequate data obtained previously when using conventional instruments. A comparison of these sets of curves shows the definite superiority of the special instrument.

In order to obtain additional data on locomotive performance, it is desirable during a test to measure

other temperatures, such as the temperature of ambient air, traction-motor armature bearings, traction-motor axle bearings, traction-motor frame, and ventilating exhaust air. These temperatures can be conveniently measured by thermocouples connected through a selector switch to a thermocouple potentiometer. Such temperature measurements are usually made while the train is at maximum speed, for which reason the vibration problem is more severe than that encountered during resistance measurement.

To eliminate the use of a conventional galvanometer such as is ordinarily employed with a thermocouple potentiometer, the type of electronic converter and balancing motor shown in FIG. 1 was employed for a visual indication of potentiometer balance.

The balancing motor used in the self-balancing resistance bridge was arranged to be quickly disengaged from the driving unit; the extension of the motor shaft was equipped with a dial for indication of rotation. True potentiometer balance was indicated when the motor stopped rotating. Unbalance of the potentiometer was indicated by rotation of the motor, the direction of rotation indicating the direction of potentiometer unbalance. A selector switch was mounted on the panel supporting the balancing motor. With this switch, either the output of the resistance bridge or the thermocouple potentiometer could be selected and fed into the electronic converter. With this arrangement, thermocouple emf could be measured at any time irrespective of locomotive vibration or motion.

FIG. 5 shows the connection diagram of the measuring equipment as used for a typical test. The armature yoke shown was applied by hand to each of two armatures in turn to measure armature-coil resistance.⁽¹⁾

Field tests with this equipment show it to be definitely superior to any equipment previously available. Fast, accurate readings can be obtained without a complicated setup or specially trained personnel.

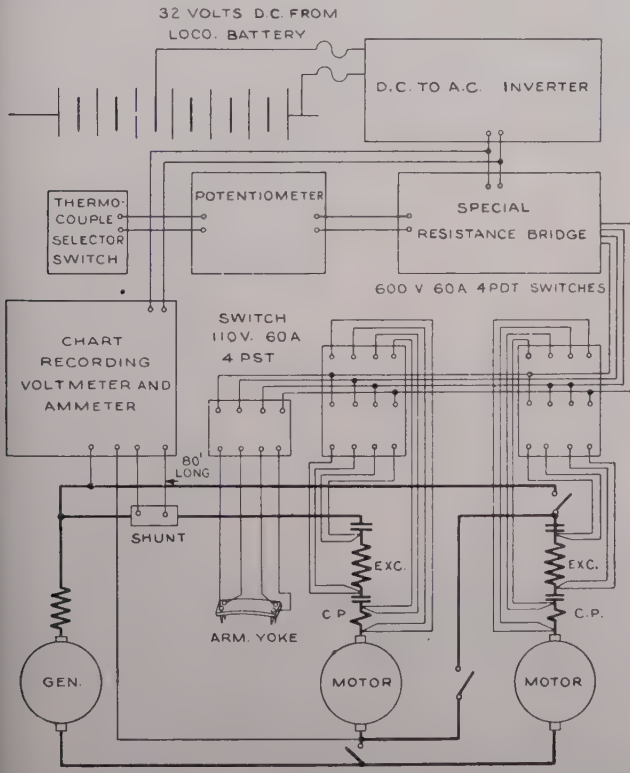


Fig. 5. Connection diagram of the temperature-measuring equipment as utilized in making a test

(1) The test method details are given in AIEE Technical Paper 45-83 "Measurements of Railway Motor Temperatures in Service," by J. W. Teker.

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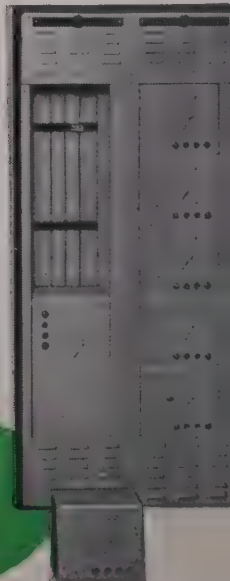


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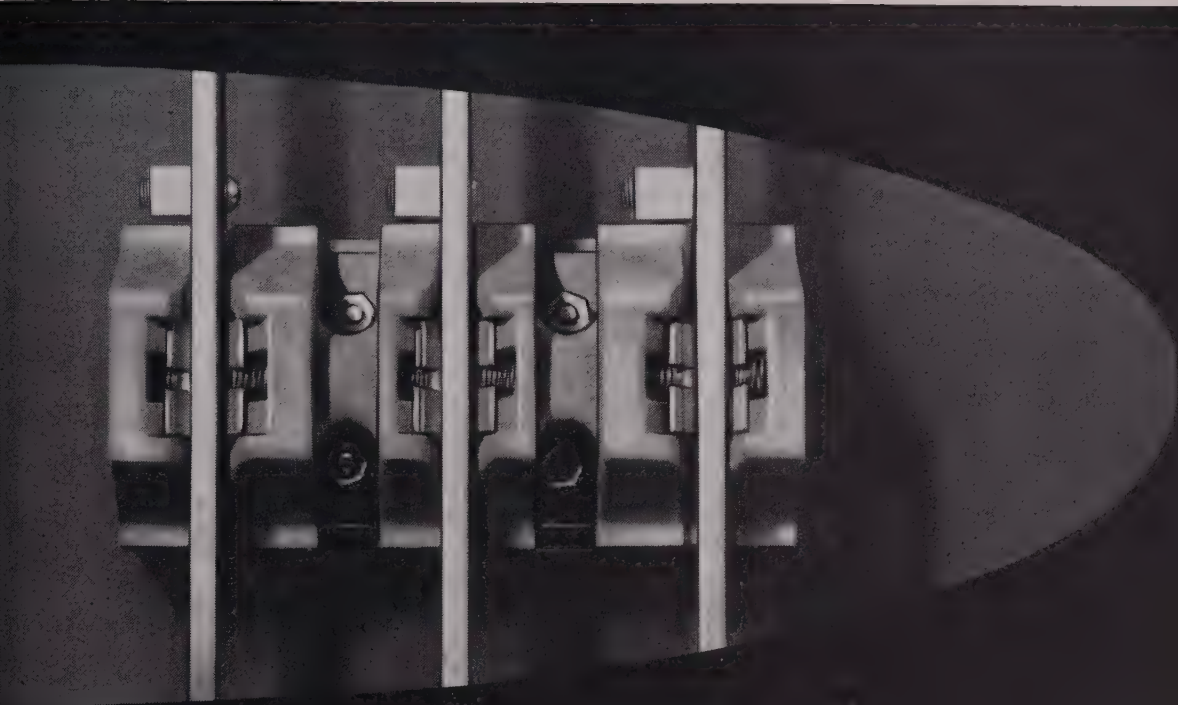
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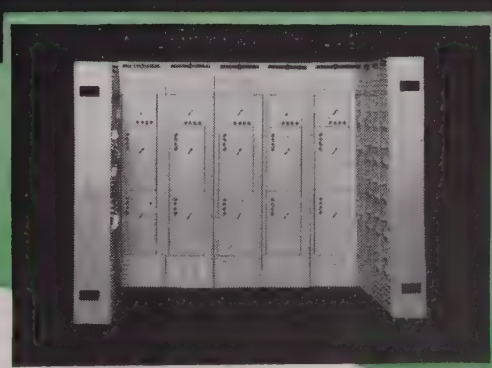
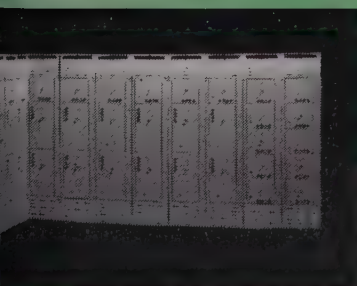
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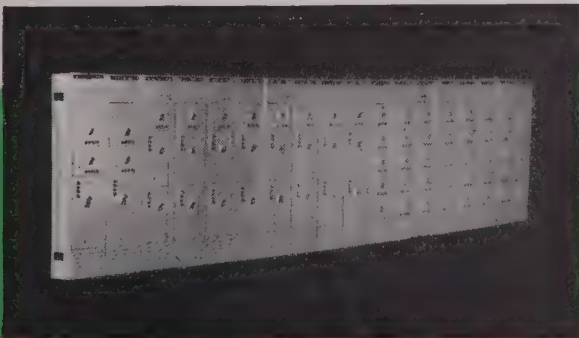


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SIMPLE CALORIMETER FOR MEASURING SPECIFIC HEAT

By measuring heat input in terms of electric energy in convenient compact laboratory equipment, the specific heats of powdered solids and of liquids can be quickly determined with good accuracy

By ROGER B. RICE

Plastics Laboratory, Chemical Department
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Roger B. Rice

IN designing molds for fabricating plastic parts, and in many other problems involving the thermal properties of plastics, it is desirable to know the specific heats of these materials. The satisfactory determination of specific heat easily and quickly, using simple and inexpensive equipment, has long been a need in this and many other laboratories. This article describes the apparatus and techniques which were developed for that purpose in the Plastics Laboratory, and which permit the quantitative estimation of specific heat of many powdered solids with accuracy sufficient for design purposes, using very simple equipment and techniques. One determination can be made in about twenty minutes.

Many excellent calorimeters which are suited to the measurement of heat capacity of poor conductors have been described in the literature. Representative of a very common type of instrument is that designed by Wilkes and Wood⁽¹⁾ in which the increase in heat of a jacketed calorimeter cup is measured after introduction of a heated specimen. Hill and Bell⁽²⁾ describe some recent modifications in Wilkes' design. Such an apparatus, although widely used, suffers from a number of drawbacks. It involves the use of several heating coils and thermocouples, with the complexity of their associated control and measuring equipment. It requires a separate furnace for initially raising the temperature of the specimen, with the attendant difficulty of transferring the sample from the furnace to the calorimeter. The total length of time required for a determination (five to eight hours) precludes its very frequent use for regular measurements.

The familiar Bunsen⁽³⁾ ice calorimeter, a modern version of which is described by Ginnings and Corruccini,⁽⁴⁾ has many excellent features and is suited to very accurate determination, but likewise requires transfer of the specimen from an external furnace. The apparatus is fairly complex and requires skilled technique for its proper operation. The time factor in making successive determinations is also appreciable, since an ice mantle must be frozen about the specimen chamber.

A somewhat different type of calorimeter is described by Andrews.⁽⁵⁾⁽⁶⁾ It is spherical or cylindrical in shape, jacketed, and has numerous copper fins radiating in-

ward to transmit heat evenly to all parts of a powdered sample. It permits determinations in a relatively short period of time (about ten minutes), and enables successive measurements to be made on the same sample without removal from the calorimeter. It is suitable for good or poor conductors. However, it, too, is a somewhat difficult piece of apparatus to construct, and

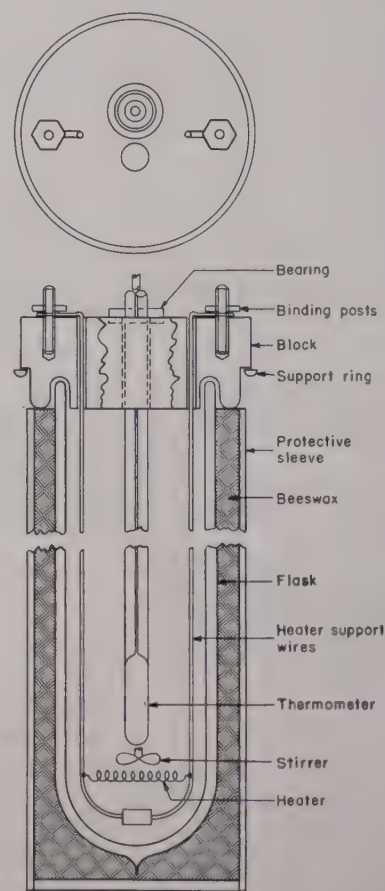


Fig. 1. Partial section of the simple calorimeter for specific heat measurements

requires the use of several thermocouples with the accessory equipment.

The operation of the calorimeter to be described depends upon determining the total heat capacity of the calorimeter plus the powdered sample suspended in contact liquid, and subtracting from this value the

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

(1) Numbered references are listed at the end of the article.

calorimeter constant and heat capacity of the contact liquid. The operation is carried out by measuring the heat input in terms of the electrical energy required to produce a measured increase in temperature of the system.

THE EQUIPMENT

The present equipment is shown partially sectionalized in FIG. 1. It consists essentially of (1) a silvered dewar flask enclosed in a protective sleeve, (2) a Nichrome heating coil suspended within the flask, (3) a glass stirrer driven by a small constant-speed motor, and (4) a hardwood block which holds the heater supports, stirrer, and thermometer in rigid alignment.

The flask is an ordinary one-quart wide-mouth vacuum bottle about 7 cm inside diameter and 29 cm tall. It is encased in a section of thin rolled plastic tubing about 10.5 cm in diameter and 34 cm long, having a fitted wooden bottom. The annular space is filled

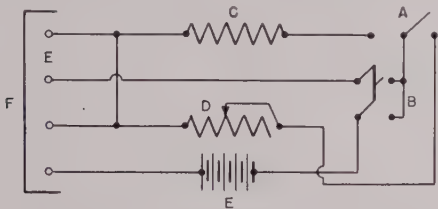


Fig. 2. Electric circuit diagram for the calorimeter
A: Calorimeter external-resistance switch
B: Main switch
C: Calorimeter heating coil
D: External resistance
E: Storage battery
F: Wattmeter

with beeswax which was melted and poured in around the flask. The sealed tip does not touch the bottom. This construction offers a little added insulation and provides considerable mechanical protection. This protection is important since any replacement of the flask necessitates recalibration of the calorimeter. The top of the flask projects about 2.5 cm beyond the protective sheath, and fits loosely into a matching groove in the block.

The heating coil is made from No. 26 Nichrome wire, wound in a helix of about 0.8 cm diameter, and formed in a doughnut shape so that it fits into the calorimeter with about 0.3 cm clearance all around. On diametrically opposite sides of the doughnut are soldered 30-cm lengths of No. 12 B&S copper wire. The ends of these pass in a snug fit through holes in the wooden block and are brought out to binding posts. At the lower end of the assembly, below the coil, the wires are extended for about one inch each and are bent toward each other until the ends are separated by about 1 cm. The ends are then fitted tightly into holes in either side of a small block of thermosetting laminate. This construction adds considerable rigidity to the heater assembly. The connecting block is streamlined so that it offers minimum hindrance to downward flow of liquid from the stirrer. The resistance of the coil (two sides in parallel) is about 2.2 ohms.



Fig. 3. The calorimeter and accessories as set up in use

The stirrer shaft is about 60 cm long and is formed from glass tubing 0.55 cm in diameter, selected for straightness. The glass paddle is double-bladed, 2.5 cm in diameter, and shaped so that its rotation causes a downward flow of liquid. At the point where the shaft passes through the wood support block there is a small ball bearing, fitted snugly to it by means of a rubber bushing. The top of the block is recessed slightly to receive the bearing. The hole in the block through which the shaft passes is considerably larger than the shaft and is not intended for any further support of the latter. The stirrer is driven by a small constant-speed motor and is coupled to the top of the shaft by a short length of heavy rubber tubing. The motor is operated independently of the remainder of the electrical equipment.

The hardwood block, in addition to having the holes already mentioned, has also a hole through which passes a Beckmann thermometer in a close fit. A rubber washer around the thermometer prevents its sliding through the hole when assembled, and facilitates vertical positioning of the bulb. As has also been indicated, the lower face of the block is grooved to fit loosely over the lip of the flask, and rests on the top of the jacket.

Electrical energy is supplied to the coil by a 6-volt automobile storage battery. The input is measured with a d-c wattmeter whose characteristics were specially designed for this particular application. A schematic diagram of the electrical circuit is shown in FIG. 2. The variable external resistance is so adjusted that its energy consumption is identical to that of the calorimeter heater.

The entire calorimeter assembly is so arranged (Fig. 3) that the flask can be removed downward, by sliding out the shelf upon which it rests, without disturbing any

other part of the setup. This feature greatly facilitates changing samples, and permits all the parts of the apparatus to remain in the same relationship to each other. This is an important consideration in obtaining consistent results. The variable external resistance, special wattmeter, and control switches can be seen in the lower righthand corner of FIG. 3.

THE PROCEDURE

Determination of Calorimeter Constant

For measurements which are to be made at approximately room temperature, a Beckmann differential thermometer is so set that room temperature reads approximately mid-scale. The thermometer is placed in its proper hole in the support block, and the apparatus

TABLE I

Time Min.	Thermometer Readings (Deg C)	Wattmeter Readings (Watts)	Operations
0.0	X.XXX		Start timer
0.5	X.XXX		
1.0	X.XXX		
1.5	X.XXX		
2.0	X.XXX		
2.5	X.XXX		
3.0	X.XXX		
3.5	X.XXX		Main switch ON: ext. resistance
4.0	X.XXX		
4.5	X.XXX		
5.0		(XX.XX)	Switch over to calorimeter heater
5.5		XX.XX	
6.0		XX.XX	Main switch OFF
6.5	X.XXX		
7.0	X.XXX		
7.5	X.XXX		
8.0	X.XXX		
8.5	X.XXX		
9.0	X.XXX		
9.5	X.XXX		
10.0	X.XXX		
10.5	X.XXX		
11.0	X.XXX		
11.5	X.XXX		
12.0	X.XXX		Finish readings

entirely assembled except for the flask. The thermometer bulb, heater, and stirrer are arranged with respect to each other approximately as shown in FIG. 1. The bulb of the thermometer should be completely submerged in the calorimeter liquid when the apparatus is assembled.

About 450 gm of redistilled carbon tetrachloride, or an equivalent volume of other contact medium, slightly below room temperature, is weighed to the nearest 0.1 gm into the flask. The height of the CCl₄ is noted, and a suitable gauge of stainless-steel strip or heavy wire is so constructed that the distance of the liquid level from the top of the calorimeter can be reproduced accurately in subsequent calibrations and determinations.

The flask is assembled with the remainder of the apparatus, and its removable shelf slid in place to support it. After making sure that the stirrer shaft runs free and the paddle blades touch no part of the coil or thermometer, the motor is started and allowed to run about five minutes. At this time the thermometer

should read within the lower inch of its scale. It can be adjusted upward by closing the switches connecting the battery with the heating coil for a moment or two, then allowing another five minutes or more to elapse.

The single-pole double-throw switch is now thrown to the external-resistance side. A strict time schedule of thermometer and wattmeter readings is then begun, using a stopwatch or electric timer. Table I illustrates the observations made and operations performed in a typical calibration or measurement run.

Since at the exact moment the calorimeter heater is turned on, the wattmeter needle may be shifting (due to the changing of the circuits), the wattage value indicated in parenthesis in Table I is derived by extrapolation of the two or more succeeding values. If the external resistance is set to exactly equal that of the calorimeter heater, and the change of circuits is accomplished rapidly, it should be possible to read the value directly. The energy input is computed by averaging the wattage figures obtained.

The net temperature increase of the system is obtained graphically by plotting on the same sheet the temperature readings obtained before and after the heating period, extrapolating the straight-line portions of each series to halftime (based on the period the heater was ON) and reading the temperature increment at that point. A typical plot is shown in FIG. 4.

The general calculation for determining the calorimeter constant is as follows:

$$K = \frac{Pt}{4.185 \theta} - Wc \tag{1}$$

where

- K = calorimeter constant (gm cal C⁻¹)
- P = average energy input (watts)
- t = time (seconds)
- θ = temperature increase (C)
- W = weight of CCl₄ (grams)
- c = specific heat of CCl₄ (gm cal gm⁻¹C⁻¹)

The factor 4.185 is a probable value of the electrical equivalent of heat in International joules per cal.⁽⁷⁾

Measuring Specific Heat of a Sample

The specimen whose specific heat is to be measured should be in the form of a powder, 40-mesh or finer. (It is desirable either to dry it thoroughly before a determination, or to know its free moisture content so a suitable correction can be made if desired.)

About half the quantity of contact liquid normally used in a test is introduced carefully into the tared calorimeter flask. Thirty to fifty grams of the powdered sample, depending upon its bulk density, is now weighed to the nearest 0.1 gm into the flask, followed by a quantity of contact liquid just sufficient to bring the liquid level to the same point as in the calibration. The total weight of the calorimeter and contents is determined to 0.1 gm and the weight of the contact liquid obtained by subtracting the weight of the calorimeter.

The calorimeter is assembled, and the same procedure followed as described under "Determination of Calorimeter Constant." The energy input and θ are calculated as previously shown. The general expression for determination of the specific heat is as follows:

$$C_s = \frac{\frac{Pt}{4.185 \theta} - (Wc + K)}{S} \quad (2)$$

where the terms c and K common to the calibration-calculation Equation (1) are the same, and where P , t , θ , and W have values specific for a determination in which

C_s = Specific heat of sample (gm cal gm⁻¹ C⁻¹)

S = Weight of sample (grams)

THE RESULTS

Calorimeter Constant

The calorimeter was calibrated using carbon tetrachloride, whose specific heat of 0.200 gm cal gm⁻¹ C⁻¹ is taken as the average of the value of 0.201 from Lange⁽⁸⁾ and 0.199-0.200 from the ICT⁽⁹⁾ at ordinary room temperatures. The procedure was as previously described, and values of calorimeter constant were calculated from Equation (1). Three determinations on two different days gave figures of 26.5, 26.4, and 26.6 gm cal C⁻¹. The reproducibility is satisfactory for the purpose of this work.

Determination on Standard Material

To check the accuracy of determination, a suitable standard material whose specific heat was accurately known was sought. It should be available in powder form, be nonhygroscopic, be insoluble in the contact media being used, and have a moderately low specific gravity.

Ginnings and Corruccini⁽¹⁰⁾ have made extensive studies on pure aluminum oxide, and have concluded that it would be an excellent material for such a standard. They determined its specific heat accurately over a wide temperature range, and found it to have a value of 0.1868 gm cal gm⁻¹ C⁻¹ (by interpolation) at 27.5 C, the average temperature at which determinations in this work were made.

Two runs using this standard, with CCl₄ as the contact medium, yielded values of 0.187 and 0.187. While

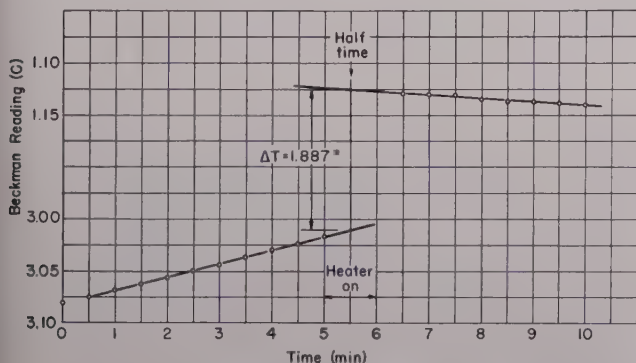


Fig. 4. Plot of temperature-time readings in typical determination

these are in excellent agreement with the value derived from Ginnings' and Corruccini's work, the curves from which θ were computed indicated that temperature equilibrium was being reached quite slowly following the heating period, thereby requiring excessive extrapolation of the straight-line portion of the cooling curve. FIG. 5 is a plot of the data from one of these runs, and shows clearly the time lag in the transfer of heat uniformly to the sample.

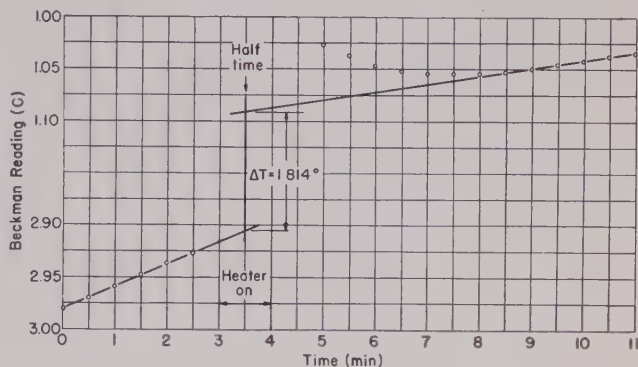


Fig. 5. Plot of temperature-time readings showing the lag in reaching steady state

Suspecting that the density of Al₂O₃ (about 4.0) was enough greater than that of CCl₄ (about 1.6) that poor agitation was resulting, a contact liquid of higher density was tried. Bromoform (sp. gr. 2.9) seemed promising, although the quantity on hand was not enough to fill the calorimeter sufficiently. Carbon tetrachloride was mixed with the bromoform until the volume was enough for a determination. The specific heat of this mixture was then determined, using the calorimeter constant previously established. Values of 0.134, 0.133, and 0.134 gm cal gm⁻¹ C⁻¹ were obtained.

Using an average figure of 0.134 for the specific heat of the contact medium, two more determinations on Al₂O₃ were made, giving values of 0.187 and 0.185. In these cases the steady-state curves exhibited no signs of excessive time lag in reaching equilibrium, and approximated very closely the shape of those shown in FIG. 4.

FURTHER CONSIDERATIONS

Choice of Contact Medium

Considerable experimenting was carried out in attempting to decide what liquid would be suitable for a contact medium. Water was an obvious first choice, but suffered from having a very high specific heat of its own and in failing to wet most of the plastic materials on which specific heat data were desired. In addition, its specific gravity was quite low relative to many of these materials, leading to poor agitation of the sample with the adverse effects indicated.

Carbon tetrachloride was finally selected because of its greater density, its good wetting characteristics, low specific heat, and the fact that the latter value is well known, making it possible to calibrate the calorim-

(Concluded on next page)

SIMPLE CALORIMETER

(Continued from preceding page)

eter with the same liquid. As mentioned, the calorimeter may be used to determine the specific heat of other liquids, which may serve as contact media where other characteristics such as density may make them more desirable.

Evaporation Loss

With volatile liquids such as CCl_4 , appreciable evaporation may take place during a run. The loss in weight (usually amounting to about a gram) was corrected for by weighing the calorimeter after each run as well as before. The calculated average weight of contact medium was then used in computing the results.

The rate of heat loss due to the latent heat of evaporation of the liquid was assumed constant throughout each half of a run and is compensated for in the plot of the steady-state curves. Actually, the rate may increase slightly during the period the heater is on, but the difference is considered negligible.

External Resistance

Originally the electrical circuit for the calorimeter provided only a single switch between the battery and heating coil. It was soon found that an initial surge took place when the switch was turned on, this being followed by a gradually changing rate of energy input

for a period of thirty seconds or more, making any accurate determination of the average energy consumption impossible. An external coil of exactly the same ohmic resistance as the heater was therefore introduced, and switched on about a minute before the calorimeter was supplied with energy. This allowed time for a steady state to develop in the electrical circuit so that, during the heating period, the wattage drop (if any) was linear. A much better estimation of the average energy consumption was thus made possible.

Determinations at Other Than Room Temperature

While studies at other than room temperature have not yet been made with the apparatus described, it would seem quite feasible to thermostat the calorimeter and make determinations either above or below room temperature, the range being limited only by the characteristics of the calorimeter materials and contact media and by the technical and practical aspects of temperature control.

General

While the values for calorimeter constant and specific heat of contact medium and standard material are not selected in the sense that "good" values were presented and "poor" were discarded, all from the same series, much data have preceded which were not at all comparable in precision or accuracy. One of the major factors in making possible results of the precision indicated for the described equipment has been the careful control of many variables, so that they are reproducible and can be compensated for in calibration of the instrument and plotting of the temperature data.

Further work will evaluate the ultimate precision of the method, and will determine the conditions necessary to handle a wide variety of materials. The figures presented merely demonstrate a good probability that the equipment and techniques have definite value in determining specific heat with sufficient accuracy for design purposes.

CONCLUSIONS

A simple, inexpensive, and easily operated calorimeter for the measurement of specific heat of powdered solids, particularly plastics, has been described. It is also adapted to the measurement of the heat capacity of liquids, and it permits a determination with an accuracy of approximately one percent in a period of about twenty minutes.

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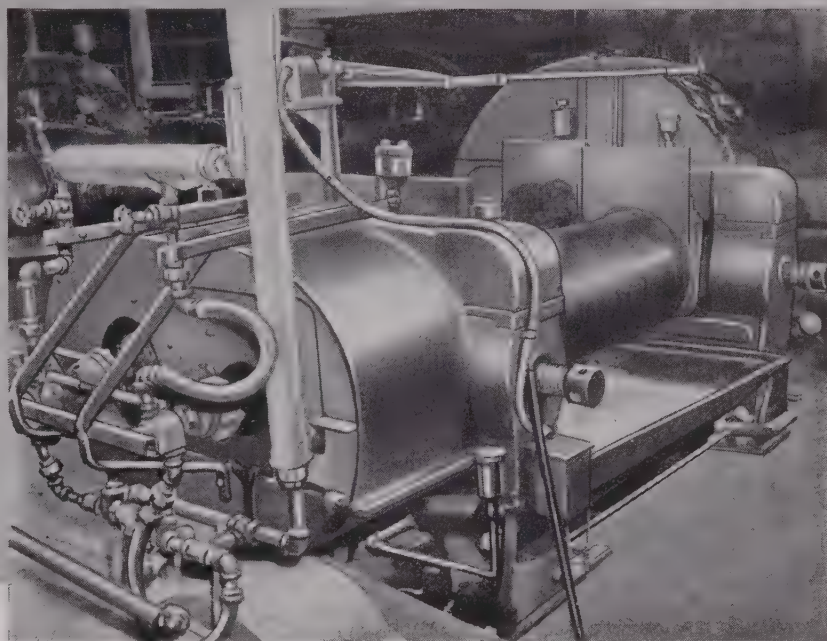
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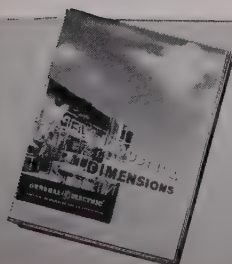
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OPTICALLY CORRECTED CELLS . . .



G. B. Buck, II

Usefulness of light-measuring instruments expanded by use of new filters and by lenses laminated to surface of the cell. Both these innovations aided also in the development of low-range and multi-range precision light meters

By G. B. BUCK, II
Engineering Division, Lamp Department
General Electric Company

THE basic significance of instruments has long been recognized in guiding research, in establishing developmental procedures, and in controlling production processes. Yet there remains another field of service, not as commonly recognized but frequently of importance. This opportunity lies in the use of instruments designed to guide the application of products and techniques. When properly designed and used, such instruments may become "catalysts" in the commercial as well as the technological development of an industry.

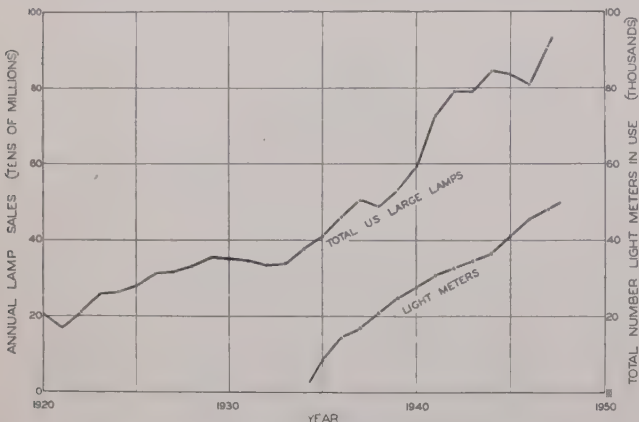


Fig. 1. Trend of annual U.S. large lamp sales prior to and after development of the light meter. The curve for the light meter is cumulative, representing the total number of instruments being used in lighting promotion

THE LIGHT METER

The widely used pocket light meter is an outstanding example of an instrument designed to guide the application of a product, in this case, of lamps and lighting techniques. The phenomenal growth of the 70-year-old lamp industry has been facilitated during the past fifteen years in no small measure by the low cost and dependable instrumentation provided by the light meter. FIG. 1 shows a striking parallel between upward trend of lamp usage and the cumulative totals of meters through the years.

Of course many other factors, for example new and improved products, progressive price reduction policies, new knowledge as to light and vision, and current economic trends have also played major roles in the lamp business. Yet the part played by this instrument has been significant as a basic tool in creating a quantitative

interest in lighting and a desire for improvement, in establishing the effects of environmental factors, and in guiding lighting practice at the point of application.

Frequently, *design* connotes *compromise*. The particular design features which originally fitted the light meter so well for its job include:

- Minimum cost
- Maximum dependability
- Small size and simplicity
- Reasonable sensitivity and precision

TABLE I
CORRECTION FACTORS FOR SELENIUM PHOTOVOLTAIC CELLS* UNDER VARIOUS LIGHT SOURCES

Source	Color	Correction Factor
Incandescent	2700° K	1.00
	2800	0.99
	2900	0.98
	3000	0.97
	3200	0.95
	3400	0.94
Fluorescent	White (3500°)	1.04
	45 White (4500°)	0.94
	Daylight (6500°)	0.84
	Soft white (A)**	0.87
	Soft white (B)	0.95
	Photocolor	0.76
	Warm white (2800°)***	1.02
	Blue-white (RF)	0.77
	Industrial white (RF)	0.79
	Blue	0.46
	Green	1.45
	Pink	0.93
	Gold	1.27
	Red	0.68
	360 BL	0.07
Mercury	DH-1	0.84
	EH-1	0.94
	AH-4	0.86
	AH-5	0.93
	H-6 (Quartz jacket)	0.66
	(Glass jacket)	0.70
	H-9	1.02
	UA-2	0.78
	UA-3	0.76
Sodium	UA-4	0.83
	Germicidal (18T8)	0.58
	NA-9	1.30
Neon	15-mm tubing at 30 ma	0.85
	Hot-cathode (C-H)	0.83
	Glow lamp	1.09
Carbon arc	Cerium-cored (50 v, 60 amp)	0.48
	Low Intensity (140 v, 14 amp)	0.31

* Computed for G-E Light Meters of current production, from most recent data available on spectral emission of sources.
** Soft White (A), made prior to April 1948; (B) made after April 1948.
*** Color discontinued in 1944.

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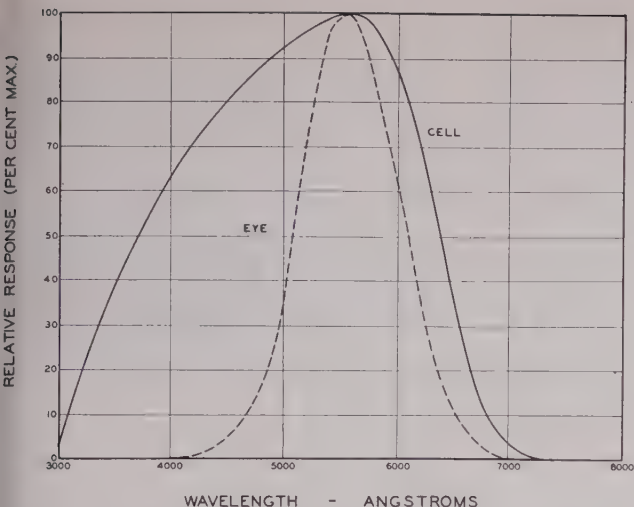


Fig. 2. Spectral sensitivity of present-day "average" light-meter cells (solid curve) and the average (International Commission on Illumination) human eye (dotted curve)

The relative importance of each of these factors may vary from one set of conditions to another, and from time to time. But the importance of the items of low cost and dependability can scarcely be over-emphasized in an instrument for widespread use by lay personnel.

COLOR CORRECTION FOR FLUORESCENT LIGHT

Nevertheless, "nothing is constant except change" and the establishment of the fluorescent lamp as a general illuminant has markedly affected the design requirements for the light meter. First, the present instrument was designed in an era when only one type of artificial illuminant, the incandescent lamp, was in common use. Thus, although the response of the selenium cell to various wavelengths differs from that of the average human eye (FIG. 2) the instrument could be calibrated under incandescent lamps and the calibration remains valid so long as the meter is used under incandescent lamps. The fact that the instrument would not read correctly under natural lighting was troublesome but was tolerable since natural lighting in in-

teriors is usually but a small proportion of the whole. However, the widespread use of fluorescent lamps, which differ greatly from incandescent in spectral emission, means that light-meter readings under these sources may be grossly in error. True, correction factors can be computed or measured for each of these sources, as in Table I. However, the mere need for such factors may lead to errors in use and undermine confidence in the instrument—and there are practical difficulties in keeping a list of correction factors at hand and then converting all readings to true values by computation.

To meet present-day conditions, color correction becomes a design requirement. Fortunately, the cell response covers a wider spectral range than the eye so that it becomes a relatively easy matter to design a filter to reduce the relative cell response to closely match the eye at all wavelengths. Through the use of such filters, the errors due to spectral differences between the measured and calibration sources are reduced to negligible proportions.

REDUCTION OF ERROR CAUSED BY SURFACE REFLECTION

A second type of error, that due to light reflection from the surface of the cell, has long been recognized as a limitation of all instruments for the measurement of light. All surfaces, whether that of a light-sensitive cell or of a diffuse test plate used with a visual photometer, have the property of reflecting a greater proportion of the incident light as the angle of incidence becomes greater. The theoretical concepts were developed by Fresnel and show that the state of light polarization, the indices of refraction of the surface, and surrounding media are the other factors involved. Fresnel's equations may be written as follows:

For light polarized perpendicular to plane of incidence:

$$R = \frac{I}{I_0} = \frac{\sin^2 (i-r)}{\sin^2 (i+r)}$$

where R = fraction of incident light reflected

I = intensity of reflected light

I_0 = intensity of incident light

i = angle of incidence

r = angle of refraction

For light polarized parallel to plane of incidence:

$$R = \frac{I}{I_0} = \frac{\tan^2 (i-r)}{\tan^2 (i+r)}$$

Thus, for unpolarized light, which may be considered as one-half polarized in each plane:

$$R = \frac{1}{2} \frac{\sin^2 (i-r)}{\sin^2 (i+r)} + \frac{1}{2} \frac{\tan^2 (i-r)}{\tan^2 (i+r)}$$

For the practical case of a piece of glass or plastic in air, measurements and theory show light reflectance to vary with the angle of incidence, as indicated in FIG. 3. Hence, one would expect the light-sensitive

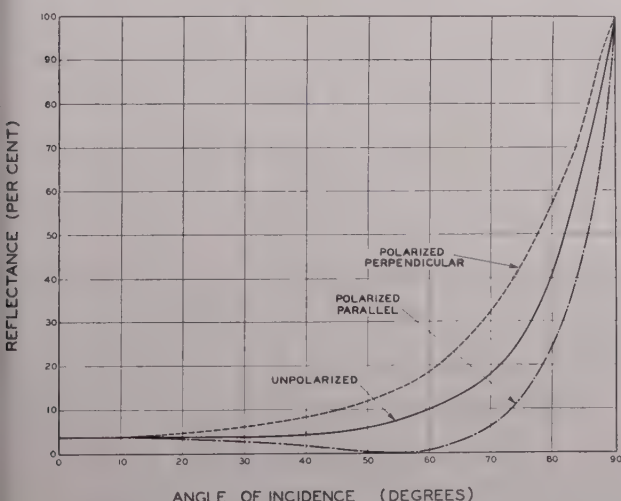


Fig. 3. Reflectance of light at various angles of incidence upon a surface; for example, glass or plastic of index of refraction of 1.490, in air

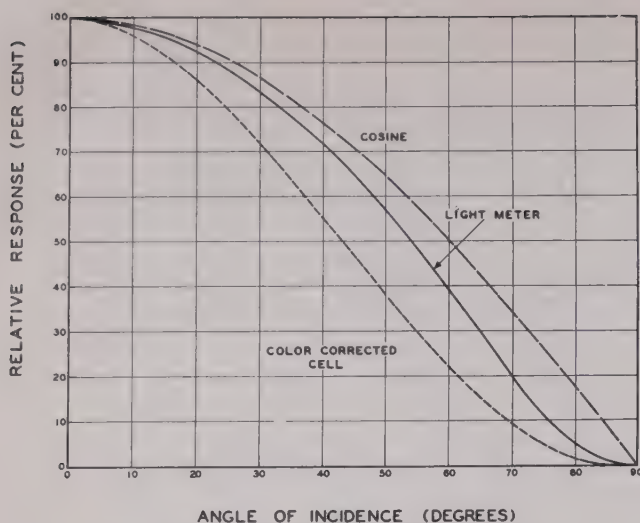


Fig. 4. Relative response of light meter (solid curve) and a cell color-corrected with glass filters (dotted curve) to light at various angles of incidence. Theoretically perfect angular response is given by the cosine curve (dashed curve)

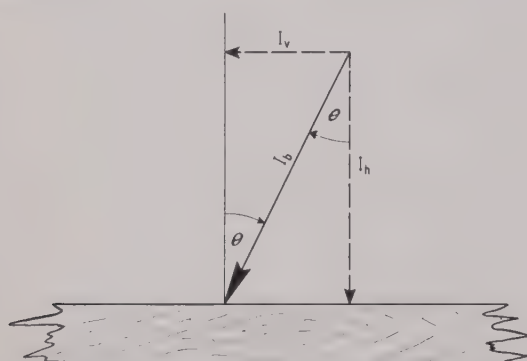


Fig. 5. Vector diagram illustrating Lambert's Cosine Law. The horizontal surface illumination is the product of the beam intensity and the cosine of the angle of incidence θ

cell to have reduced response at grazing angles of light incidence. Furthermore, one might expect that covering the cell with a protective layer of glass or with color-correcting filters would further lower the relative response at wide angles, due to light reflected from these additional surfaces. Studies presented in FIG. 4 have revealed that this is exactly what happens. The

dashed line is the theoretical cosine curve, which should be matched by relative cell response because the horizontal component of the light intensity is the product of the beam intensity and the cosine of the angle of incidence, FIG. 5.

When the variation from the cosine curve is plotted in terms of percent error, we may summarize as FIG. 6 the optical performance of the light meter as to color and angular response.

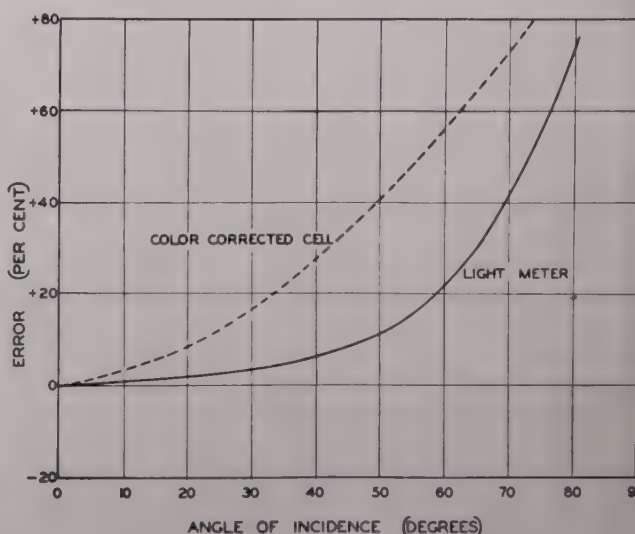
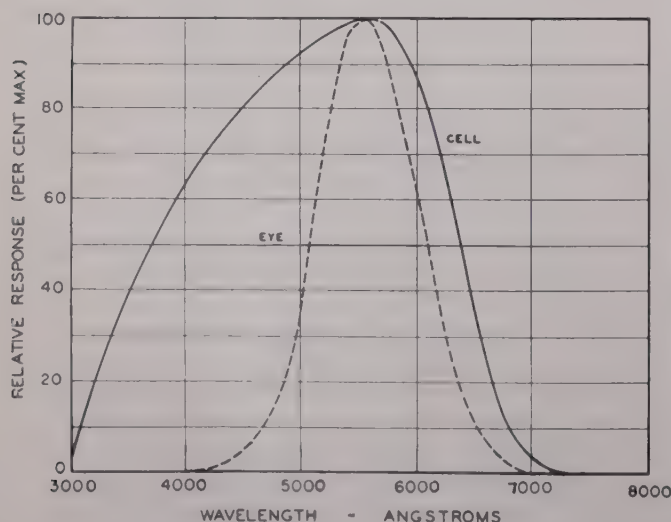
Since the light losses were seen to be due chiefly to surface reflections, it became obviously desirable to study the effect of eliminating the surfaces by laminating lenses to the cell. After a number of trials, a lens shape was designed to substantially correct for the remaining surface and filter losses, and that resulted in the improved instrument shown in FIG. 6. It will be noted that the laminated cell is somewhat over-compensated in one plane and under-compensated in the other. The necessity for this arises from the asymmetric shape of the rectangular cell and yet the need for a continuous lens surface for ease of manufacture and maintenance. The lens was so designed that the errors tend to compensate under the usual lighting condition wherein light is incident on the working surface from many angles.

LOW-RANGE AND MULTI-RANGE PRECISION METERS

The optical accuracy of the improved light meter is now well within the 5 to 10 percent figure which



Fig. 6. Summary chart showing present light meter, its spectral response compared to that of the eye, and its angular errors compared with values given by the cosine law



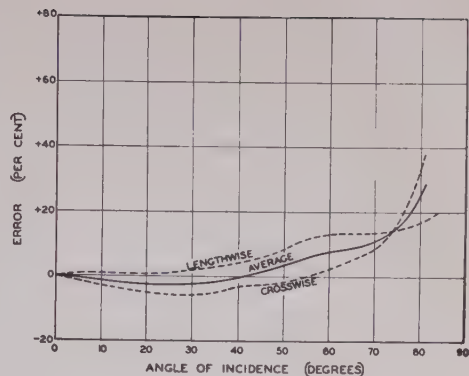
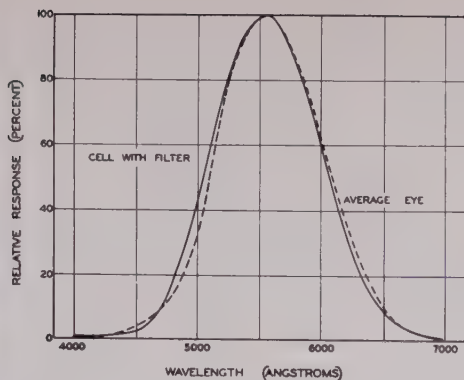
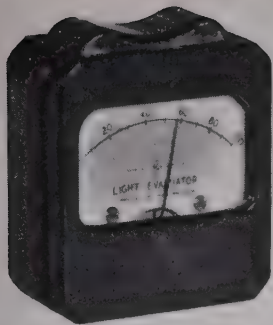


Fig. 7. Summary chart of the new light evaluator, its spectral response compared to that of the eye, and its angular errors compared with values given by the cosine law

suffices for a pocket instrument. However, the potential improvements through the laminated-cell construction were so great as to lead to the development of two new precision instruments, one for very low intensities and the other for a wide range of incident flux. To approach a perfect cosine response, a symmetrically shaped cell was needed; and the size selected was 4 in. in diameter in order to achieve full-scale deflections, for street-lighting and other important low-intensity applications, with only one footcandle or less. A simple lens was developed and the angular response is that of the cosine law within usual error of measurement.

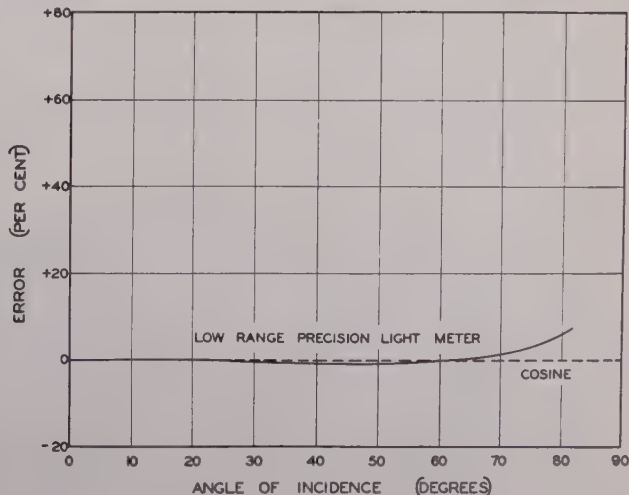
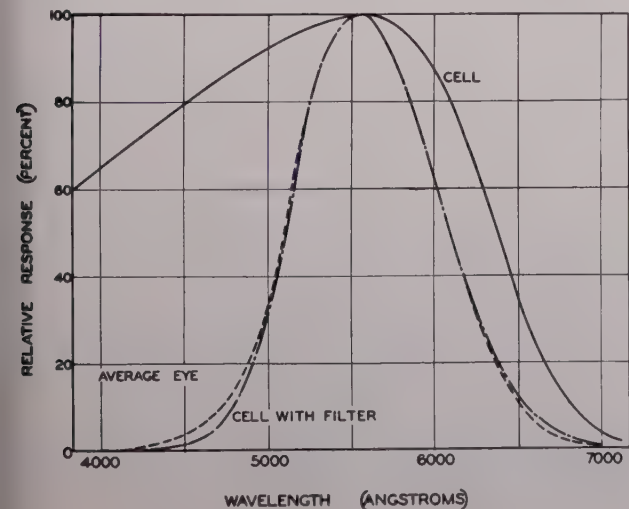
FIG. 8 shows the new low-range precision light meter and its angular-response characteristics. The earlier multicell diffusing-plate light meter is shown in FIG. 9. The sensitivity of the new meter is 100 times that of

the pocket meter and 50 times that of the multicell meter. Correction factors may be used for sources other than incandescent, or a hemispherical filter may be placed over the cell and the filter factor used to convert scale readings to true footcandles. Since this is an instrument that ordinarily will be used by skilled technicians, the former procedure may be preferred.

For conditions where color correction is needed, a multirange precision light meter has been developed to utilize the same 4-in., circular, laminated cell. The hemispherical plastic filter provides color correction without appreciably changing the angular-response characteristics, FIG. 10. It is interesting to note that much-improved color and angular responses have been attained with about 14 times the optical efficiency of the earlier instrument.



Fig. 8. The new Low-Range Precision Light Meter, its spectral response with and without filter compared to that of the eye, and its angular errors compared with values given by the cosine law. The instrument is calibrated without a filter for maximum sensitivity



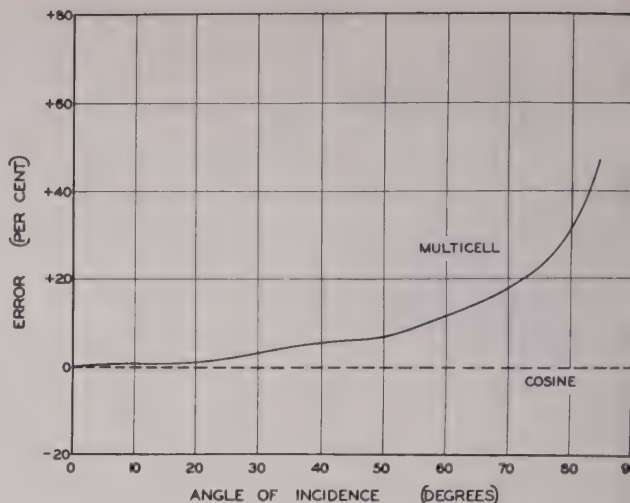
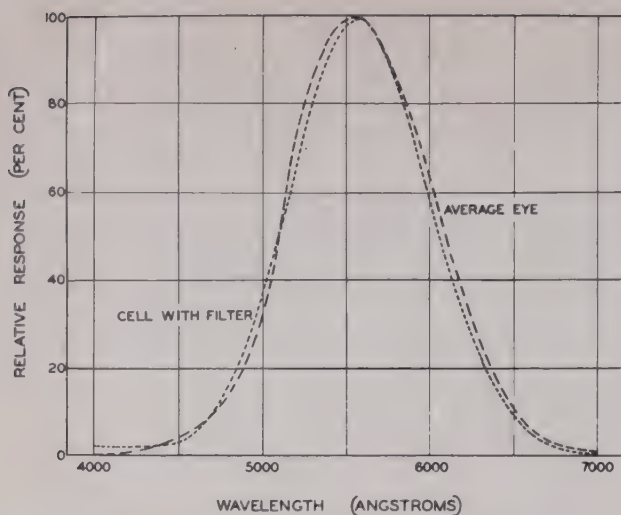


Fig. 9. The earlier multicell diffusing-plate light meter, its spectral response compared to that of the eye, and its angular errors compared with values given by the cosine law

SUMMARY

A new technique of laminating lenses to the surface of light-sensitive cells has provided the means for marked improvement in cell response for light at grazing incidence. This development, combined with new color correcting filters of higher transmission, forms the basis of design for several new instruments. These include specifically: a new pocket light meter, corrected for color and angle of light incidence; a low-range precision light meter, with full-scale deflection of 1 footcandle on one scale and 5 footcandles on the other, and with nearly perfect cosine response; and a multiscale precision light meter which includes a hemispherical color correcting filter and has three sensitivity ranges: 0 to 10, 0 to 100, and 0 to 1000 footcandles.

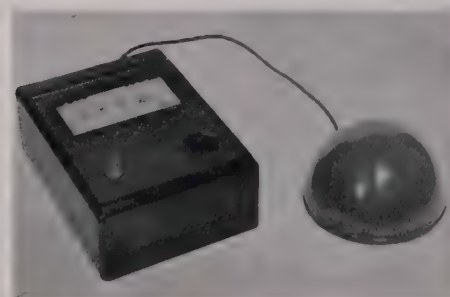
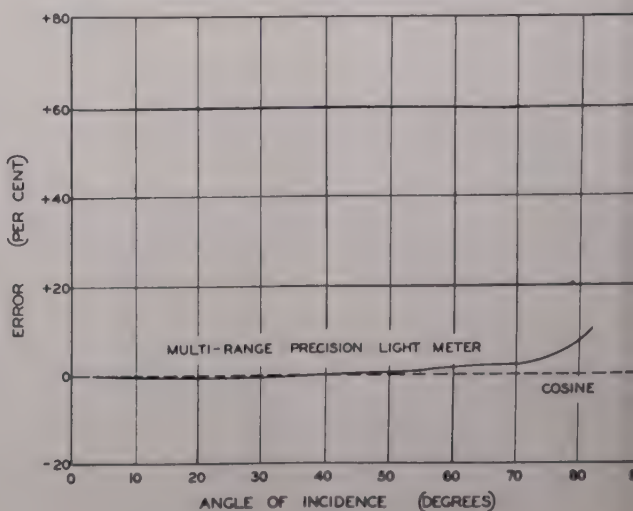
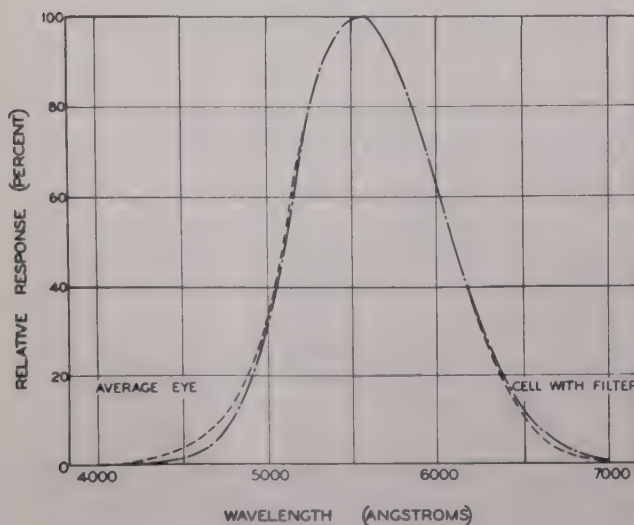


Fig. 10. The new Multi-range Precision Light Meter, its spectral response compared to that of the eye, and its angular errors compared with values given by the cosine law. The instrument is calibrated with the hemispherical filter in place



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MICRODETERMINATION OF OIL CONTENT IN PETROLEUM GREASES

Extracting minute representative samples of grease from bearings in service and quickly applying test procedure gives a reliable indication of condition of the grease

By A. E. BAKER, Jr.

Thomson Laboratory
General Electric Company



A. E. Baker, Jr.

FOR engineering investigations of grease lubrication and greases, it became necessary to develop a new method of analysis so that small amounts of grease of the order of 50 to 100 milligrams—an amount that can be removed on a pencil tip—could be analyzed for its oil content. A procedure of this nature thus makes it possible for the engineer to follow in detail the deterioration of grease in used or failed bearings. At any time during the operation of a motor, a shutdown of a few minutes is ample time in which to extract the minute sample. This will in no way disturb the grease or its continued operation in the bearing. The micro-analysis of the minute samples of grease taken periodically will reveal the oil content at any time during the life of the lubricant.

PROCEDURE

Weigh out approximately 100 mg of grease on a glass rod, handling with cork-tipped tweezers as shown in FIG. 1. Weighings can be made on a good analytical balance. Remove the rod from the holder and smear the grease around the inside of a double-thickness micro Soxhlet fat-free paper thimble. Leave the rod in the thimble and insert the thimble into the micro Soxhlet extractor. Add 15 milliliters of C.P. benzene to a tared extraction flask and assemble the apparatus as shown in FIG. 2. Extract over a water bath for approximately one hour; then remove the extracting flask and carefully evaporate the benzene over the same water bath.

To the extracted oil in the flask, add 15 ml of 0.05N alcoholic potassium hydroxide, and reflux for one hour. Filter the oil-alkali solution through a Whatman No. 41H filter paper into a 60-ml separatory funnel. Rinse the flask two or three times with 10-ml portions of petroleum ether, adding the washings to the funnel. Wash the filter paper with 5 ml of petroleum ether. Add 10 ml of 50 percent ethyl alcohol to the separatory funnel; shake vigorously one to two minutes, then draw off the alcoholic layer. If separation does not occur within a few minutes, add $\frac{1}{2}$ to 1 ml of 95 percent ethyl alcohol. Repeat washing with 50 percent ethyl alcohol.

The combined alcohol washings are then placed in a second separatory funnel. Rinse the flask with 10 ml of

petroleum ether and add this to the alcohol washings; shake vigorously and allow layers to separate. The addition of 95 percent ethyl alcohol will aid separation. Draw off the alcoholic layer and discard. The petroleum-ether layer is added to the original petroleum-ether solution which is then, finally, washed three to four times with 10-ml portions of 50 percent ethyl alcohol. Shake vigorously before drawing off the alcohol layers, and discard the alcohol washings.

The petroleum-ether layer is then drawn off into a previously weighed micro Soxhlet extraction flask (dried at 100 C). Wash the separatory funnel with a few milliliters of petroleum ether and add to the extraction flask. Carefully evaporate the solvent over a water bath. Wipe the flask dry. The addition of a small amount of strong ethyl alcohol to the flask will aid in evaporating any water. Dry in an oven at 100 C for

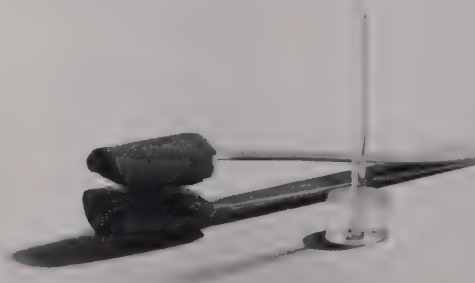


Fig. 1. Equipment for handling grease samples

approximately one-half hour. Cool in a desiccator and, finally, weigh the extraction flask. The resulting difference in weight of the flask, plus contents, multiplied by 100, and divided by the weight of the grease sample taken, gives the percent oil content of the grease.

COMPARISON WITH MICROANALYSIS

Table I shows a comparison of results obtained by the ASTM macro test (128-40) and the new microprocedure to actual values of the percent oil in test greases.

Because some greases do not contain a large excess of fat and fatty acids, it is possible to apply a single

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

TABLE I
**COMPARISON OF ASTM 128-40 AND MICRO-
PROCEDURES FOR OIL CONTENT**

Test Grease	Vendor's Analysis (Percent)	ASTM 128-40 (Percent)	Microanalysis (Percent)
1	82	81	80.1
2	79	80.5	80.14
3	83	79	82.35
4	76	79.5	76.7
5	71	70.25	72.0
6	78	70.3	77.25

microextraction without saponification. Results are as shown in Table II.

TABLE II
OIL CONTENT DETERMINED BY MICROEXTRACTION

Test Grease	Vendor's Analysis (Percent)	Microanalysis (Percent)
7	78.9	79.15
4	76	76.7

A further check on the accuracy of the micro method was to analyze samples of grease that had been subjected to a long-time bleeding and evaporation test similar to that outlined in Army-Navy Aeronautical Specification AN-G-3. The particular grease was maintained at 75 C for 6500 hr. Table III shows the results.

TABLE III
**OIL CONTENTS OF BLEEDING AND EVAPORATION
TEST GREASE**

Test Grease	Computed Percent Oil	Microanalysis Percent Oil
1	77.3	79
	76.8	77.6
	77.2	78.2

The results listed in Tables I to III thus indicate that the microprocedure is an accurate and reliable method for determining the oil content of greases.

APPLICATION

During the past year, the microprocedure for the determination of percent oil in petroleum greases has been applied to the analysis of used greases taken from failed bearings in functional bearing grease testers.⁽¹⁾

Because drops of free oil can exist in the bearing, as a result of bleeding and working of the grease while lubricating the bearing, it is important that samples taken are as nearly representative of the grease in the bearing as possible. Thus, in each instance the minute

samples were extracted from a point nearest the balls and race of the failed bearing and preferably at the top, since the free oil may run down to the bottom side of the bearing, forming a pocket of oil after shutdown. A sample taken on the bottom side, of course, would give erroneous results. It is possible, too, that drops of oil may be trapped on the sides and top of the bearing, but it is believed that samples taken from such locations more nearly represent the true condition of the grease.



Fig. 2. Micro Soxhlet extraction and saponification apparatus

The data in Table IV are the results of the periodic testing of two greases run in functional grease testers operating with No. 306 deep-groove radial ball bearings at 100 C and 3600 rpm.

TABLE IV
**OIL CONTENT OF GREASES vs. OPERATIONAL
HOURS IN GREASE TESTERS**

Grease No. 2 Operational Test Hours	Percent Oil	Grease No. 4 Operational Test Hours	Percent Oil
123	75.8	247	64.9
181	77.0	340	57.3
269	72.0	587	25.6
293	69.9	676	28.3
550	77.5	670	41.5
710	72.6	1260	39.0
725	73.0		
789	70.2		
2072	64.7		
2929	62.8		

The data exhibited in Table IV show that the gradual decrease in percent oil of the grease is reasonably consistent with the increasing number of opera-

⁽¹⁾"Life Measurement of Ball Bearing Grease," by Dr. D. F. Wilcock, GENERAL ELECTRIC REVIEW, Oct. 1947, p. 37.

tional hours. However, the importance of obtaining a fairly representative test sample each time can not be overemphasized. It is obvious from the oil contents obtained on grease No. 4 in Table IV that the grease

TABLE V
OIL CONTENT vs. OPERATIONAL HOURS ON
GREASE NO. 8

Percent Oil	Operational Hours
78.9	150
73	300
75.2	450
68.3	600
65.4	750
65.8	900
69.5	1050
68.9	1350
67.2	1500
61.0	2250
60.9	2550
60.7	3150
63.4	3750

samples were not truly representative. The general trend nevertheless still exists.

It is the practice at the present time to determine percent oil on all greases after bearing failures in the grease testers. The results of several tests on grease

No. 8 indicate that bearing failures occurred when the oil content reached values between 50 and 60 percent. It was further ascertained that these failures were due to grease breakdown and not to some mechanical cause. Thus, with this information available on grease No. 8 a test was run under the same operational condition with periodic oil tests being made to determine whether it might be possible to predict failure of the bearing. A tabulation of these data is given in Table V.

Thus, from the data in Table V, one would expect bearing failure to occur shortly, since the oil content at 3750 hr was approaching the critical range of oil content at which previous failures of grease No. 8 had occurred. Actually, however, the failure occurred at 4376 hr. Thus there appears to be a possibility of determining bearing failure due to grease breakdown provided the oil content characteristics of the grease for particular operational conditions are known.

CONCLUSION

For many years, samples of oil have been taken from steam turbines and analyzed for neutralization number, interfacial tension, and oxidation resistance. As a result of the large amount of accumulated data, it is now possible to approximate the useful life remaining in the turbine oil. Comparatively, however, there is little data available on the microdetermination of percent oil in used bearing greases, and it is realized also that grease lubrication of ball bearings is an exceedingly complex problem involving many factors; nevertheless, it is somewhat gratifying to learn from preliminary investigations that there may be a possibility of determining the useful life remaining in a grease from a knowledge of the oil content. Compilation of future data will prove or disprove this hypothesis. To establish the correlation surmised in this investigation, the following prerequisites are thus necessary: (1) a knowledge of the oil content of greases at failure for any particular operating conditions; and (2) the extraction of a representative sample of the test grease.

APPENDIX

The properties of the several greases used in this investigation are listed in Table VI.

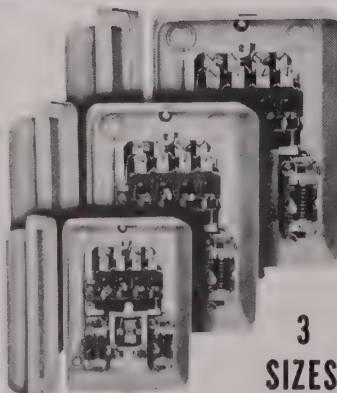
TABLE VI
GREASE PROPERTIES

Properties	No. 1 Soda	No. 2 Soda	No. 3 Soda	No. 4 Soda	No. 5 Soda	No. 6 Soda	No. 7 Soda	No. 8 Soda
Soap Base	Lime	Lime	Lime	Soda	Lime	Lime	Lime	Soda
Percent Soap	18	21	17	25	29	22	22	24
Percent Oil	82	79	83	76	71	78	78.9	76
Viscosity of Oil SUS at 100 F	150	300	400	308	700	312	283	300
Melting Point F	228	347	345	370	374	219	316	450
ASTM Penetration	297	285	339	197	230	187	278	285

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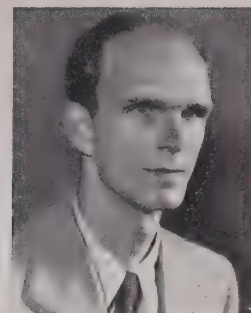
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GAMMA-RAY STUDIES . . .

Spectrum analysis and absorption measurements. New laboratory setup uses betatron, Geiger counters, special auxiliary equipment

By J. L. LAWSON
Research Laboratory
General Electric Company



James L. Lawson

IN MAKING use of the gamma radiation from high-energy particle accelerators for quantitative measurements in nuclear research, it is usually necessary to know the spectral distribution of intensity. The experimental determination of the spectral distribution of gamma rays is a problem of considerable complexity.

Spectrum analysis involves two phases, namely, (a) the separation of the frequency (energy) components of the beam, and (b) the measurement of the intensities of these components.

SEPARATION OF FREQUENCY COMPONENTS

Dispersion by a crystal lattice is impractical because of the extremely low angular separation at gamma-ray frequencies. It is possible, however, to utilize secondary effects for sorting out the various energies. The two phenomena that are available for this purpose are the Compton effect (scattering of x-rays by electrons) and pair production (the conversion of a gamma-ray photon into an electron and a positron). The use of the Compton effect is complicated by the fact that the energy of the incident quantum is divided between the recoil electron and the secondary quantum. Since the latter cannot readily be measured, this process does not lend itself to spectrum analysis. In pair-production, which occurs in the electric field of an atom, virtually all of the energy of the gamma-ray quantum appears in the secondary particles and hence can readily be measured. The gamma-ray frequency may be obtained from the relation

$$h\nu = 2m_0c^2 + E_1 + E_2$$

where m_0 = rest mass of the particles

E_1 = kinetic energy of electron

E_2 = kinetic energy of positron

ν = frequency of gamma ray

c = velocity of light

h = Planck's constant

Pairs may be produced by bombarding a thin target with the beam of gamma rays. It is then necessary to separate the particles according to their energies. This may be accomplished by deflecting them in either a magnetic field or an electrostatic field. For practical reasons, at high energy the former is more satisfactory. When a magnetic field is applied at right angles to the direction of an incident gamma ray, the secondary electrons are

deflected to one side and the positrons to the other. The kinetic energy of a particle is then determined from the magnitude of its deflection and the strength of the field.

MEASUREMENT OF COMPONENT INTENSITIES

The second aspect of spectrum analysis is the measurement of the intensities of the components after they are separated. This involves counting the relative number of pairs in equal energy intervals corresponding to different energy values. The number of pairs per energy interval (frequency interval) plotted against the energy gives the pair-production spectrum. Using the relative probability for pair formation as a function of energy (the cross section), one can calculate the intensity spectrum from the pair distribution.

One method of gamma-ray spectrum analysis employs the cloud chamber operating in a magnetic field; the paths of the secondary particles are then made visible by the condensation of water droplets on the ions produced by the particle in its course. The tracks are recorded by photographing the cloud chamber at the instant of expansion. Electron-positron pairs are identified by oppositely curved tracks emanating from a common origin. Because of the direct visibility of phenomena, cloud chambers have proved to be invaluable in the identification of types of reactions. The essential difficulty of the cloud-chamber method lies in the large number of pictures necessary to make the determinations statistically accurate. Not only is the obtaining of an adequate number of records an arduous and time-consuming undertaking, but the task of analyzing the photographic data is a forbidding one.

Various methods are available for recording pair production. In all of them the sensitivity of the detector to the secondary particles is an important factor. Photographic methods suffer from uncertainties regarding the response characteristics of the emulsion to excitation by particles of different properties and energies. Ionization chambers are characterized by good efficiency but variable and uncertain sensitivity. The Geiger-Mueller counter is well adapted to the detection of the secondary particles because its counting efficiency can be made practically 100 percent at all energies. It is necessary, however, to so design the counter system that it will identify (a) the type of particle, (b) the origin of the particle, and (c) the type of reaction responsible for the particle.

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

The Research Laboratory has designed and constructed a new type of gamma-ray spectrum analyzer in which the positive and negative electrons are detected and their paths identified by a series of Geiger counters suitably disposed about the inner periphery of a large vacuum chamber. The equipment is illustrated schematically in FIG. 1. The x-ray beam passes first through a collimator and into the vacuum chamber where the electron-positron pairs are produced by the reaction between the beam and a target of absorbing material. The counters, about one hundred in all, are mounted inside an aluminum tank, approximately four feet square and one foot deep, supported between the poles of an electromagnet. They are arranged in two series, one on each side of the path of the direct beam. Thus, electrons are counted on one side and positrons

oerstedts for sweeping charged particles out of the beam. The brass chamber containing the elements of the collimator is attached to the vacuum chamber of the analyzer by means of a sylphon bellows so that both are evacuated by the same pumping system.

The complete unit, including the collimator, weighs about eight tons and is made mobile by mounting on trucks. In use, a beam of gamma rays from a chosen source enters the analyzer through the collimator and strikes the radiating target, which is in the form of a ribbon about four inches long and a few thousandths of an inch thick. The radiating target must be thin so that electrons and positrons produced in the foil will not be scattered by the target itself and thus not be registered by the proper counter. Several target specimens are mounted on a rack, which can be manipulated from outside the tank so that the targets can readily be

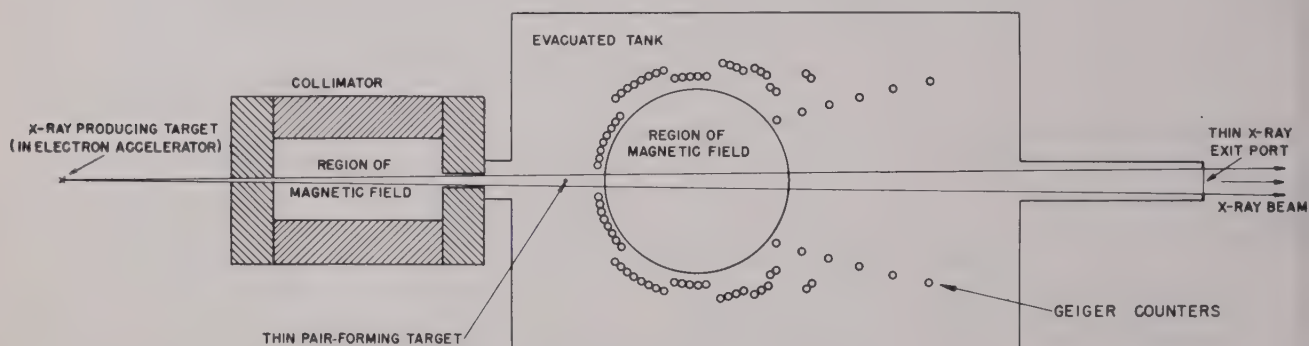


Fig. 1. Schematic diagram of spectrum analyzer

on the other. Within each series, the counters are properly spaced and connected in groups representing distinct and equal energy intervals. The calculation of the pattern in which the counters are assembled was an important part of the design of the analyzer. The tank is evacuated to a pressure of 10^{-5} mm of mercury to eliminate scattering by gas molecules. The photograph of FIG. 2 shows the tank with one side removed.

The response of the counters is registered on a complicated electronic tabulating system which registers single electron and positron counts over the complete range of energies and also sorts out the pairs and tabulates them according to the total energy of the pair. A total of about three hundred vacuum tubes is used in the tabulating circuit. A pair is indicated by the simultaneous reception of only one electron and only one positron. The probability of chance coincidences (the simultaneous registration of an electron and a positron that are not members of a pair) can be calculated from the data on single counts and can be kept to a sufficiently low value by the control of gamma-ray intensity.

An important part of the apparatus is the "collimator" for the gamma-ray beam (see FIG. 1). The function of this device, which is not a collimator in the literal sense, is (a) to remove undesired radiation and (b) to provide a limited beam of the desired radiation. Essentially, it consists of a series of apertures in lead plates for the purpose of defining the gamma-ray beam and a permanent magnetic field of several thousand

interchanged. Spectral analysis is achieved by counting for a given exposure, the relative number of pairs representative of each energy interval.

The complexity of the equipment is necessitated by two factors: (1) the confusion resulting from chance coincidences, which must be eliminated from the final results; (2) the need for discriminating between the various disturbing factors, such as inadequacies in theory and spurious experimental effects. A great advantage of this system is the large amount of data that can be taken and analyzed in a relatively short time. In intermittent working periods over a six-month interval, a total of approximately 10^7 pairs have been registered and analyzed. To obtain and process an equivalent amount of data by conventional cloud chamber methods would require about three hundred years of actual working time.

EXPERIMENTAL PROCEDURE AND RESULTS

This equipment is designed for two types of experiments: (1) an experimental check of the theory of pair production through accurate determinations of cross section; (2) measurements of spectral distribution of gamma rays under a variety of conditions.

(1) *Measurement of Cross Sections.* The first step in checking pair-production theory is the determination of total cross sections from absorption measurements. Absorption measurements are important because they indicate the total loss of energy from all causes—the

photoelectric effect, the Compton effect, and pair production. Since absorption theory must take account of all of these factors, the experimental determination of absorption coefficients constitutes an excellent over-all confirmation of theory. Measurements of gamma-ray absorption coefficients at approximately 90-Mev gamma-ray energies have been made by comparing the counts corresponding to the chosen energy, both with and without a block of absorbing material introduced in the beam. In making absorption measure-

these three calculated values does not agree precisely with experimental values; the ratio of the experimental value to the theoretical value varies linearly with the square of the atomic number. This probably indicates the failure of the Born approximation in yielding the theoretical cross section for pair production. Even in light elements, however, where the Born approximation should be valid, there is a slight discrepancy between theory and experiment which may be because of the inadequacy of the Fermi-Thomas atom model.

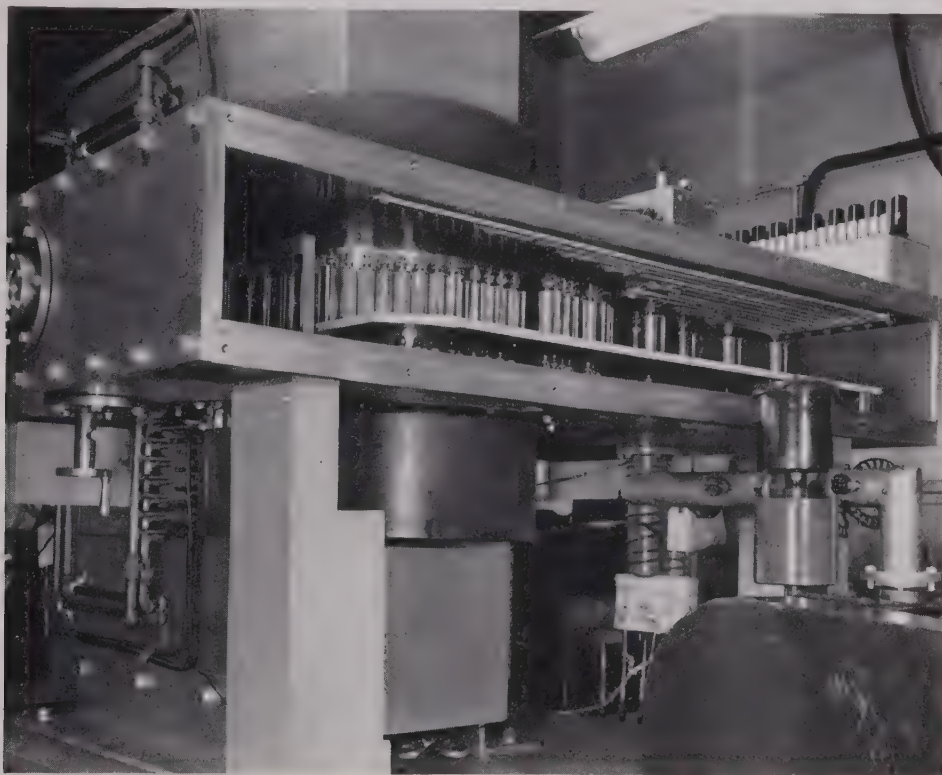


Fig. 2. Interior of gamma-ray spectrum analyzer, showing Geiger-Mueller counters, electromagnet, and vacuum system

ments, only the highest energy interval can be utilized, since this eliminates the disturbing influence on the absorption coefficient of secondary gamma rays of the same energy. If the highest energy interval is not used, the measurement includes not only the intensity removed from energy interval employed, but also the intensity contributed to it from higher-energy gamma rays that are scattered into the lower-energy range.

These absorption measurements are complicated by two limitations: (a) the relatively few quanta in the maximum energy range, and (b) the short duty cycle which demands high peak intensities in order to yield a reliable average counting rate.

The present status of the correlation between theory and experiment may be summarized as follows. According to present theory, the three principal contributions to the cross section are: pair production in the field of the nucleus,⁽¹⁾ pair production in the field of atomic electrons,⁽²⁾ and Compton scattering.⁽³⁾ The sum of

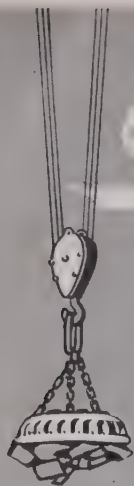
From the total cross section one could determine the individual pair and Compton cross sections, if he could determine the absolute size of one of these quantities or the relative magnitude of one in terms of the other quantity. Neither of these determinations appears to be easy with the pair spectrometer; however, it is possible to measure the *ratio* of pair cross sections in different elements by using pair-forming targets of different elements having known weights. One can use this ratio with the total cross sections to determine essentially the ratio of Compton scattering to pairs, from which one can then obtain separately the absolute cross sections of Compton scattering and pair formation. This is illustrated by the following example. One can write

$$\sigma = \sigma_p(1 + \alpha) \quad (1)$$

where σ is the total cross section, σ_p is the pair cross section, and α is the ratio of non-pair to pair cross section (theoretically Compton to pair cross section). For the sake of illustration we may write an equation

(Concluded on next page)

⁽¹⁾ Calculated by Bethe and Heitler using the Born approximation and the Fermi-Thomas model of the atom.
⁽²⁾ Calculated by Wheeler and Lamb by the methods of Bethe and Heitler.
⁽³⁾ Can be calculated accurately by the Klein-Nishina formula.



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GAMMA-RAY STUDIES

(Continued from preceding page)

for each of the two elements, beryllium and lead, similar to Equation (1):

$$\frac{\sigma_p^{Be}}{\sigma_p^{Pb}} = \frac{\sigma_p^{Be} (1 + \alpha^{Be})}{\sigma_p^{Pb} (1 + \alpha^{Pb})}$$

At high energies α^{Pb} is low; for example, at 90 Mev α^{Pb} is theoretically 0.02. This figure can be assumed in Equation (2) without much risk; if it is wrong it does not greatly affect the result. One measures the ratio

of pair cross sections, $\frac{\sigma_p^{Be}}{\sigma_p^{Pb}}$, by using pair-forming targets

of Be and Pb having known weights and by counting the relative numbers of pairs of various energies actually produced. Since the total cross section can be found by absorption, one can use Equation (2) to determine essentially α^{Be} (theoretically about 0.3 at 90 Mev). This experimental value of α^{Be} may then be used with the experimental value of σ_p^{Be} from absorption to obtain both σ_p^{Pb} and the Compton scattering coefficient.

Using this procedure, an experimental value of α has been obtained that agrees with the theoretical value within an experimental error of approximately twenty percent. This shows that the contributions of pair production and Compton scattering to the total cross section are approximately those predicted by theory and that no other process exists in this energy range whose cross section is comparable to that of the other processes.

(2) *Measurement of gamma-ray spectra.* Having determined pair-production cross sections, one can have confidence in converting pair spectra to gamma-ray spectra. When this is done using the 100-Mev betatron as a source of gamma rays, the resulting gamma-ray spectrum is in essential agreement with the computed gamma-ray spectrum based on the Bremsstrahlung process.

ACKNOWLEDGMENT: The work described in this article was supported by U.S. Navy contract N7 ONR-332

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HIGH LIGHTS AND SIDE LIGHTS

Metals Tested by Ultrasonics

A device which uses ultrasonics, or high-frequency sound waves, to discover and record small flaws in metals has been developed. Known as the Ultrasonics Materials Tester, the instrument shoots 1,000,000-cycle-per-second sound waves through the metal to be tested, and simultaneously plots a graph which indicates any flaws in the metal's interior.

Testing of metals with the new instrument is carried out by immersing the specimen in oil, since these sound waves will not travel through air. A small transmitter, wired to the main body of the instrument and also immersed in the oil, sends the sound through the oil and through the metal specimen. The sound wave continues in its original path until it reaches the receiver on the far side of the container, or until it is interrupted by any crack or fault in the metal. A dial on the instrument will indicate this flaw, while the line on the permanent graph will dip sharply.

The transmitter is a small crystal which is made to vibrate and produce sound waves by an electric current. The receiver is a similar crystal, mounted opposite the transmitter and connected to a separate power supply.

Diesel-electric Units for the Andes

The Argentine State Railway has accepted the final design drawings for 65 double-unit diesel-electric locomotives. Featuring compact design with streamlined appearance, the locomotives are being built in three types to cover unusual operating conditions found on Argentina's railroads.

Largest of the three types will be 23 twin-unit, 2000-hp locomotives designed

Doing It with Mirrors



This instrument measures the light output of streetlights from all angles. The mirror, here reflecting the image of the engineer making a test, may be moved through a full circle around the light. At any point in the circle, light beams striking the mirror are reflected to an electric eye 25 ft away, which measures the light coming from the luminaire at that particular angle. The object of the test is to make sure that the light from the unit goes where it is needed most

for operation in the Andes, where tracks go up two-and-one-half-percent grades at 15,000 ft above sea level. Each cab will contain a 1000-hp diesel engine, which will power 12 motor axles.

For operation on the plains, especially in the vicinity of Buenos Aires, another twin-type unit will be built which will be identical with the first type but will have eight motor axles instead of twelve, with one idle axle in the center of each truck.

The remaining thirty locomotives will each comprise two units nominally rated

1000-hp each. These also will have eight motor axles but will differ from the other types in that they will be powered by two 500-hp diesels in each cab.

Having more horsepower per ton than any meter-gage units previously designed, these locomotives will enable the Argentine railroads to run heavier trains on faster schedules, thus adding to the capacity of the railways and giving better service to the country. The design is a direct result of a six-month study made in Argentina last year.

Radar Now Helps Get Sardines To Market

Radar, famed electronic wartime development to detect the enemy in spite of darkness, fog, or storm, will now help gather sardines for market from waters off the coast of Maine. An electronic navigator has been installed aboard a sardine carrier of a Maine canning company.

The device will enable the carrier to find fish seines in spite of weather conditions and thus speed up delivery of perishable sardines to the company's canneries. Overcoming the effects of fog and stormy weather, long the friend of the sardine, will not only increase the total catch but help assure more regular employment at the canneries.

The radar set will not locate the fish themselves, but is expected to strengthen the link between the carrier and fishing grounds for greater production and efficiency. Additional units may be placed in operation within the near future.

Similar to types now being used by a number of ocean-going and Great Lakes vessels, this application of the unit is believed to be the first Atlantic Coast use of radar on fishing boats.

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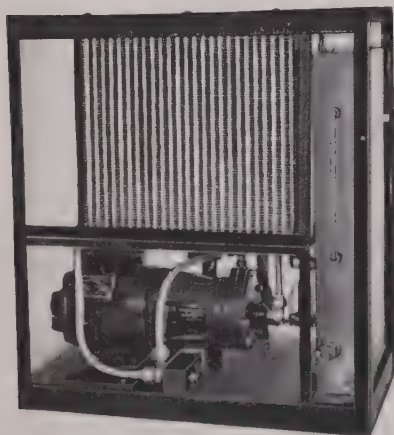
NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Template

A circle template No. 40 for use in all fields of drafting and delineation for quickly and accurately making small size circles. A series of 39 circles are designated numerically by 64ths and marked with corresponding common fractional dimensions. The template is made of 0.030 matte-finish mathematical-quality cellulose-nitrate sheet. All circle cut-outs are precision milled with allowance for pencil point to give the utmost in accuracy. Each circle is clearly marked and all have center guide lines. Printing is on negative side to prevent wearing off.—*Rapidesign, Inc., P.O. Box 592, Glendale, Calif.*

Heat-transfer Unit

A new heavy-duty heat-transfer unit, designated as Model No. 5, for cooling the magnetron power tube in an induction-heated oven. The unit is also suitable for cooling the tubes and condensers in television transmitters, short-wave communication equipment, radar sets, and for general



laboratory use. The heat generated by the magnetron tube is dissipated at the rate of 11,000 Btu's per hour, by circulating a cooling medium through the tube. The absorbed heat is then discharged into the air by means of a radiator and fan.

The unit will dissipate 3000 watts within a temperature rise of 40 F above ambient. It is equipped with a special reverse-flow radiator, 12-in. diam even-flow cooling fan, two-stage centrifugal pump, three-gallon reservoir, thermostat, flow switch, filter, and necessary fittings.—*Eastern Industries Inc., 296 Elm St., New Haven 6, Conn.*

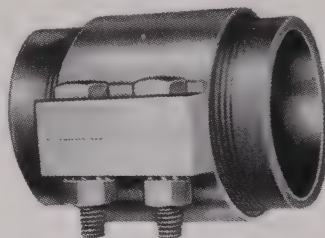
Electrical Wire

Neolay Type RU wire, 30 percent smaller in diameter than conventional building wire has a hard shell of nylon over the rubber insulation, giving the conductors better protection. It takes up less room in conduit, permitting the use of more conductors. Under the nylon are two layers of insulation: natural rubber and neoprene synthetic rubber. The nylon is hot and liquid when applied over the rubber and, as it cools, it becomes extremely hard and smooth.

The wire is claimed to be resistant to gasoline, oil, fire, moisture, acids, and light, and will be marketed in sizes 14, 12, 10, 8, and 6, for wiring homes, offices, factories, hotels, and other buildings.—*United States Rubber Co., Rockefeller Center, New York.*

Split Couplings

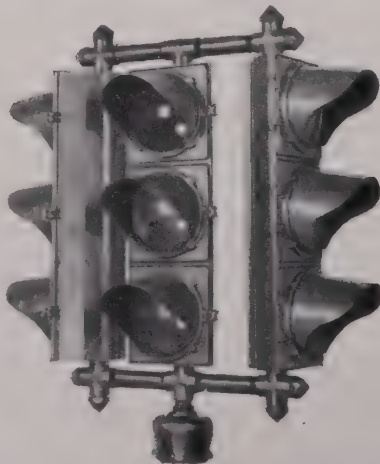
The addition of three new split couplings increases a line to 12 sizes, ranging in conduit size from the new 1/2 in. to 5 in. The coupling itself is of simple one-piece malleable iron construction. By elimination of running thread it is necessary only to butt the conduit ends together within the split



coupling and tighten down two nuts. Bolt heads are held in place by the coupling shoulder. There is no need to twist the conduit. Spring-steel lock washers prevent the nuts from loosening, and the threaded inside of the coupling meshes with the conduit threads, giving a no-slip sure-grip permanent connection. As nuts are tightened, the smooth edges of the machined flanges fit snugly together, making a dust-tight joint.—*O.Z. Electrical Manufacturing Co., 262 Bond St., Brooklyn 2, N. Y.*

Traffic Signals

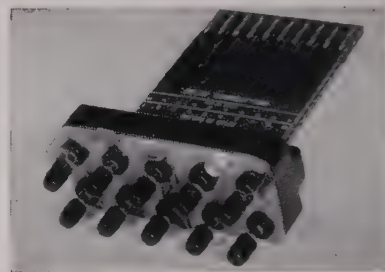
A new line of adjustable-type traffic signals with an optical system completely redesigned to eliminate reflector deficiencies and inaccuracies. The signal is available in models ranging from one-way, one-color to four or more ways with unlimited signal indications per signal face. It is interchangeable



able with other G-E signals manufactured in the past ten years and has the same external appearance.

The optical system uses a new sagged glass reflector which is supported in the housing and remains in the signal when the door is open. A positive dust-tight seal between the reflector holder and the door is made by a crowned air-cored resilient extruded gasket. Lens protection is provided by the same gasket because it envelops the periphery of the lens.—*General Electric Co., Lighting and Rectifier Divisions, Apparatus Dept., River Works, West Lynn, Mass.*

Relay Test Plug



A new test plug for drawout relays designed to make testing of relays easier and quicker than heretofore. The new plug is made of sturdy plastic molding, and all terminals are mounted on the vertical front of the plug. Each terminal is clearly marked on the front, eliminating the necessity of counting stud or relay connections. Stud terminals are colored bright red; relay connections are black. A complete set of hardware, including shorting bars and clips for test leads, accompanies each plug.—*Switchgear Divisions, General Electric Company, Philadelphia, Pa.*

Pyrometer Controller

A proportional current-input electronic pyrometer controller, Model IE486, proportions current input to electrically heated furnaces, ovens, plastic molding machines, salt pots, and other similar equipment to provide practically straight-line temperature control. The instrument does this by time modulation of the input energy. The average energy supplied is proportional to the deviation of the temperature from the control point throughout a band width which is adjustable from 0 to 2 1/2 percent of full-scale reading.—*The Bristol Co., Watbury 91, Conn.*

Control Equipment

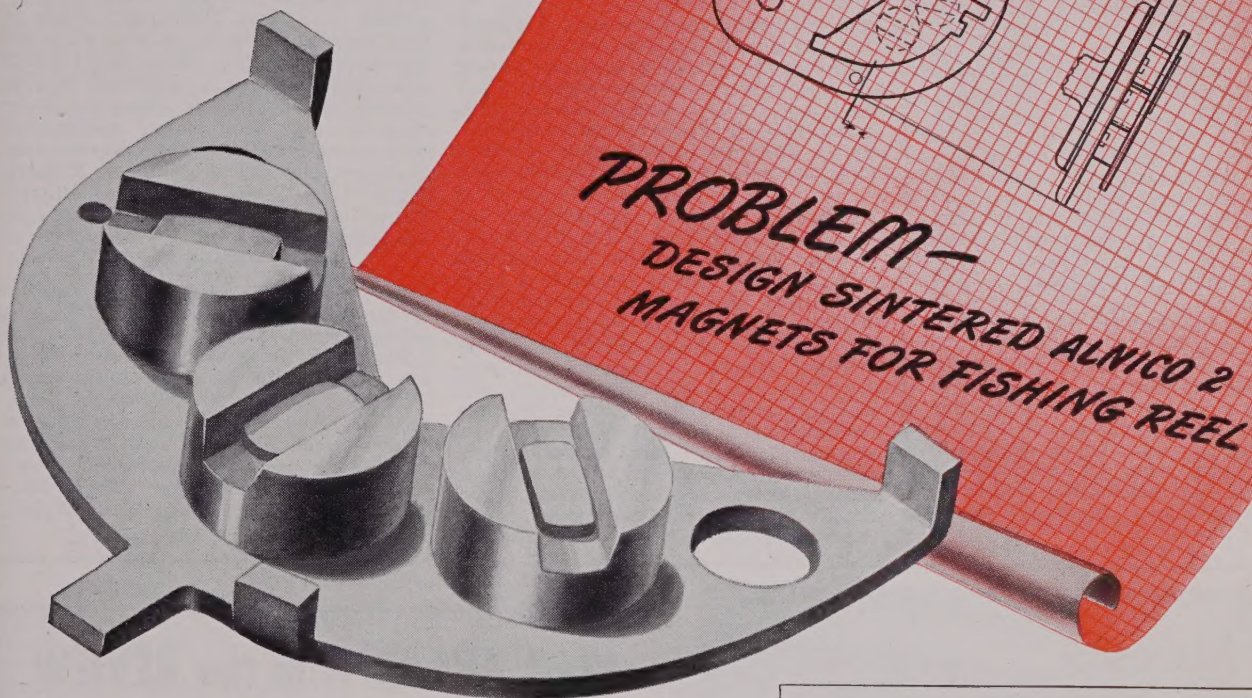
A new addition to the Emdco line is explosion-proof control equipment for use in refineries, utilities, and other industries where safe dustproof and waterproof conditions



are of first importance. A typical installation is the assembly of five motor-control groups, each providing complete control for four motors, as shown in the illustration. This assembly includes junction boxes, sealing fittings, and combination housings. Assemblies are free-standing but they can be designed for wall mounting if so desired. This equipment is available with or without instrumentation.—*Electro Mechanical Devices Co., 49 Selden, Detroit 1, Mich.*

YOU GET QUALITY PLUS ENGINEERING SERVICE WITH G-E PERMANENT MAGNETS

The three G-E permanent magnets shown below produce an automatic braking effect in the new Bristol Electromatic Reel manufactured by the Horton Manufacturing Co., Bristol, Conn.

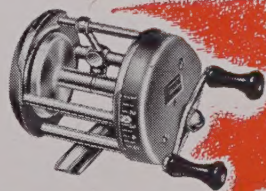


The magnets that brake your reel

Now it's G-E permanent magnets for greater accuracy in casting. The permanent magnets shown above develop a non-friction braking action directly in proportion to the speed of the plug. Maximum braking is applied at the start of the cast and, as the spool is slowing down, the braking effect decreases automatically.

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Perhaps there's a use for G-E permanent magnets in your product. Or, you may wish to improve your present magnet design for greater efficiency. Our engineers will be glad to work with you to improve your product. For details and your free copy of CDM-1, G-E PERMANENT MAGNETS, write Metallurgy Division, Section CR-10, Chemical Department, General Electric Company, Pittsfield, Mass.



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Three G-E Sintered Alnico magnets are mounted on a non-magnetic plate having adjustable air gap. A bi-metallic disc of copper and steel mounted on the end of the spool cuts the lines of force of the permanent magnets. The eddy currents induced set up electromagnetic poles which repel the permanent magnet poles producing a drag on the speed of the spool. Since the strength of the electromagnetic poles depends on the speed of rotation of the spool, this braking effect is automatically applied at all times in just the right amount. Outstanding advantages of this new reel are smooth casting action, greater accuracy, and freedom from backlash.



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TRADE LITERATURE

AIR FILTER—Development, operation, advantages, voltage requirements, design features, specifications, characteristics, and installation data of a dry-type electronic air filter are given. Diagrams and photographs supplement the text. Bulletin No. 257. Twelve pages.—*American Air Filter Co., Inc., Louisville 8, Kentucky.*

CAR UNLOADER—The details of the mechanism, power requirements, and operation are given, together with several photographs of actual stages of operations during the process of unloading grain. Folder No. 2294. *Link-Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.*

COMPRESSOR—Information concerning the Pac-Air compressor, a self-contained air-cooled gasoline-engine-driven unit for use by building contractors and farmers, is pictorially and concisely presented in this folder. Form 145. Eight pages.—*Ingersoll-Rand, Phillipsburg, New Jersey.*

LIGHTING EQUIPMENT—The Sky-Glo luminous louvered lighting system is the subject of a comprehensive bulletin which contains numerous architectural drawings, layout diagrams, and installation photographs, as well as engineering charts and specification tables. The text provides complete information on composition, sizes and shapes, construction, and assembly. Bulletin SG. Twenty-eight pages.—*Benjamin Electric Mfg. Co., Des Plaines, Ill.*

MILLIVOLT METER—Described in this bulletin is a d-c vacuum-tube millivolt meter for general measurements of d-c potentials in amplifiers and power supplies. The application, grid current measurements, contact potentials, measuring electronic current, and its operation are among the subjects included in the textual material. Bulletin II—105. Four pages.—*Millivac Instruments, P.O. Box 3027, New Haven, Conn.*

PLASTICS—Facilities for design, moldmaking, and molding are described, as well as such products as sealing caps and sleeves, mycalex, silicone rubber, high-frequency insulation, and high- and low-pressure laminates. Property tables are included. Bulletin No. CDP-578. Fifteen pages.—*Chemical Dept., General Electric Co., Pittsfield, Mass.*

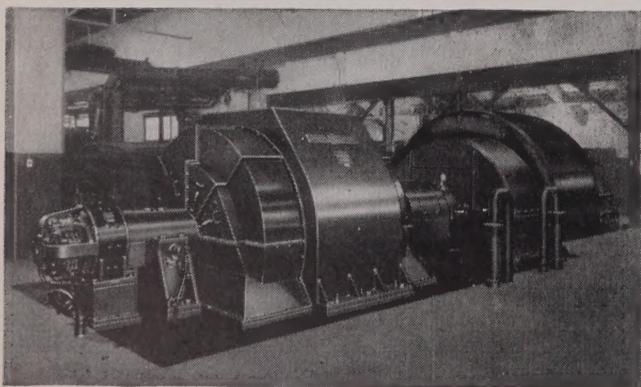
RESISTORS—Complete specifications and characteristics for Type MP high-frequency resistors are given in this technical data bulletin. Power ratings are from $\frac{1}{4}$ to 90 watts, and there are eight terminal types. Bulletin F-1. Four pages.—*International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.*

TESTING MACHINE—An electronic machine, the Electromatic, for testing films, fiber, strip, paper, textile, yarn, rubber, leather, and fine wire is described and many of the essential components are illustrated. Bulletin 37. Four pages.—*Tinius Olsen Testing Machine Co., Easton Road, Willow Grove, Pa.*

WELDERS—The general construction and operating mechanism of motor-driven press welders are presented in this bulletin. Mechanical and electrical specifications are listed. Bulletin 3-123. Seven pages.—*The Taylor-Winfield Corp., Warren, Ohio.*

WELDING ALUMINUM ALLOYS—The phases of spot welding of aluminum alloys covered in this technical bulletin include surface preparation, equipment, techniques, testing of spot welds, as well as sections on other aspects of the subject. The material is well organized and neatly assembled, and is printed on coated stock. There are many diagrams and photographs, specification charts and data tables. An extensive bibliography appears at the end. Bulletin titled "Spot Welding Aluminum Alloys." Thirty-six pages.—*P. R. Mallory & Co. Inc., Indianapolis, Ind.*

X-RAY—Beginning with the first great discovery of Roentgen, this booklet tells how x-rays are produced and traces their development to the present profound achievements including the two-million-volt Coolidge tube and 100,000,000-volt betatron. Touching on such topics as x-ray in medicine, industry, and new vistas, the booklet is appropriately titled "The Story of X-ray." Thirty-six pages.—*General Electric X-Ray Corp., 4855 West Mc Geoch Ave., Milwaukee 14, Wis.*



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BOOK REVIEWS

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INTRODUCTION TO THE DIFFERENTIAL EQUATIONS OF PHYSICS

L. Hopf; translated by Walter Nef—Dover Publications, Inc., New York. 1948. 160 pp. \$1.95.

This translation of Professor Hopf's little book on differential equations is a very welcome contribution to American engineering education. In only one hundred fifty-two $4\frac{1}{2}$ -by $6\frac{1}{2}$ -in. pages he explains the fundamental equations of physics and applies them to a variety of problems ranging from the oscillations of a string and the flow of heat in a rectangular body to the propagation of waves and the motion of the planets.

It is recognized more and more that all kinds of engineering problems are solved by the application of a very few basic equations of physics. For this reason many teachers are giving new thought to presenting the theory of differential equations in the way best suited for engineering use rather than for mathematicians only.

In presenting this volume, the author brings to us some of the European teaching experience that has helped in the formation of so many distinguished physicists and scientifically trained engineers who now play a prominent part in American technical progress.

P. L. ALGER

THE GENIUS OF INDUSTRIAL RESEARCH

D. H. Killeffer—Reinhold Publishing Corp., New York. 1948. 273 pp. \$4.50.

The best method of doing industrial research is often a mystery even to the man doing the work. This book attempts to teach good and productive ways of performing research from the point of view of the individual worker. To do so the author makes generous use of direct quotation, of men responsible for several successful researches, on how the particular researches were performed. While the examples are drawn mainly from the field of industrial chemistry, the methods they teach are applicable to all fields.

The author debunks the idea of "flash of genius" or accidental solving of problems in favor of the more productive method involving good work and thought. Two general methods may be used in research. One involves random searching, or the "Edisonian" approach, and the other a theoretical approach in which a theory is first evolved and then laboratory work is performed to prove the theory. Ordinarily, a combination of the two approaches is used.

The book is logically organized and very readable. The quotations—such as Irving Langmuir telling of the discovery of gas-filled lamp bulbs, Thomas Midgley on Freon refrigerants and ethyl gasoline, and George Oenslager on rubber-vulcanization accelerators—make the book highly interesting to a variety of readers in many fields.

J. R. ELLIOTT

TELEVISION—HOW IT WORKS

Seymour D. Usan and others—John F. Rider Publisher, Inc., New York. 1948. 203 pp. \$2.70.

Here, in clear language easily understood by the serviceman, the radio amateur, and those acquainted with broadcast radio, the principles of the television receiver are explained. General aspects of the complete television system are also presented. The section on antennas would be very helpful

in selecting the type of and the location for the receiving antenna.

The theory of the circuits found in most television receivers is presented in great detail. The material covers such circuits as the RF inputs, the ratio detector, the sound and video IF traps, the d-c restorer, the synchronizing circuits, and the associated picture-tube circuits. At the same time, the circuits used by the different manufacturers for the same function are considered. General alignment and servicing procedures are given, and the method of analyzing faults from the appearance of the picture-tube screen is also depicted.

"Television—How It Works" is an interesting nonmathematical exposition. It provides excellent background for the serviceman and the experimenter.

ALLEN E. SMOLL

CENTRIFUGAL AND AXIAL FLOW PUMPS

A. J. Stepanoff—John Wiley and Sons, Inc., New York. 1948. 438 pp. \$7.50.

Dr. Stepanoff's book should be welcomed by plant and machinery designers and students interested in pumps. The first five chapters cover the theory and background necessary to understand the presentation of pump design and test data in the following seven. The background material is brief, however, and some additional knowledge is needed for easy reading of the book. The last six chapters treat operating conditions and special problems.

The book has the following noteworthy features: The same methods and treatment of impeller design and layout are used for centrifugal, mixed-flow, and axial-flow pumps. A single diagram represents the performance data, the velocity triangles, and the design constants of centrifugal pumps for any impeller discharge angle. Curves are presented of the performance of centrifugal pumps operating beyond their normal ranges; these include negative heads, speeds, and flows. A good treatment of cavitation is included. Data are presented on the pumping of viscous fluids and the effect of stuffing boxes on shaft critical speed. The bibliographies at the end of the chapters total 195 items. Many good cross sections of pump designs and installations are shown.

To this reviewer, at least, it will be a comfort to refer to this English text instead of having to struggle with Die Kreiselpumpen and a limited knowledge of German, as has been his custom.

B. O. BUCKLAND

IMPROVING SUPERVISION

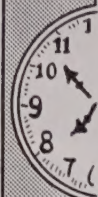
Frank Cushman and Robert W. Cushman—John Wiley & Sons, Inc., New York. 1947. 232 pp. \$2.50.

Written for all supervisors but devoting most attention to factory supervision, this book presents a clear picture of the ramifications of a supervisor's job. Treating in some detail the responsibilities of the supervisor both to his men and to his superiors, many causes of friction and misplaced effort are pointed out.

While the book is informative and instructive in itself, it would lend itself particularly well to group discussions or classroom work, where the problems presented could be taken up in more detail as they specifically applied to a particular operation or industry.

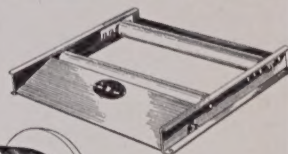
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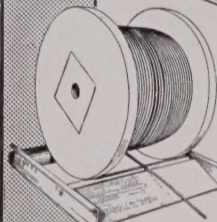


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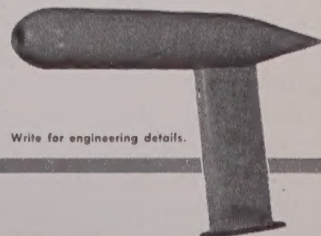
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THE ACETYLENE CYLINDER—INDUSTRY'S UNIQUE CONTAINER, by Charles Ness.

Weld. Jour., June 1948; v. 27, pp. 445-449.
Its construction, performance, testing, and safety.

ELECTRIC DRIVE

VARIABLE-SPEED CONTROLS HIGHLIGHT OF MACHINE TOOL FORUM.

Elec. Mfg., June 1948; v. 41, pp. 92-97, 192, 194, 196.

Increasing interest shown in variable-voltage d-c drives, with various types of power supplies, and in automatic cycle controls at 12th Westinghouse Machine Tool Electrification Forum.

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MULTIPLE WELDING PROCEDURES, by E. O. Courtemanche.

Steel, June 14, 1948; v. 122, pp. 93-95.

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HIGH VOLTAGES IN ELECTRONICS, by Walter E. Peery.

Mach. Design, June 1948; v. 20, pp. 123-127.

Formulas and charts furnish data on correct spacing between conductors for prevention of sparking and corona effects.

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Factory Man. & Maint., June 1948; v. 106, pp. 66-72.

An analysis of our supply of machine tools, particularly in its relation to industrial mobilization.

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IMPROVED SCHLIEREN APPARATUS, by Frank W. Barry and Gilbert M. Edelman.

Jour. Aero. Sci., June 1948; v. 15, pp. 364-365.

An optical instrument that is used in the study of supersonic flow phenomena.

NEUTRONS

NEUTRON POLARIZATION, by D. J. Hughes and others.

Phys. Rev., June 1, 1948; v. 73, pp. 1277-1290.

The production of polarized neutrons in magnetized iron has been studied with the use of the intense neutron beams available at the Argonne heavy-water pile.

PILOT PLANTS

SYNTHETIC-RUBBER PILOT PLANT, by J. V. Hightower.

Chem. Engng., June 1948; v. 55, pp. 100-102.

Describes a pilot plant, designed in 1942, which has been making low-temperature rubber, following methods suggested or developed in this country and Germany.

SUPERSONIC SPEEDS

INSTRUMENTATION CONQUERS THE SONIC BARRIER, by M. F. Behar.

Instruments, June 1948; v. 21, pp. 505-509.

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